POWER PLANT ENGINEERING

Established Over 36 Years

VOL. XXXVI CHICAGO, JANUARY 1, 1932 No. 1

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Contents of back issues of Power Plant Engineering will be found in Industrial Arts Index, on file in public libraries.

Published on 1st and 15th of each month, copyright 1932, by the

Technical Publishing Co., 53 West Jackson Blvd., Chicago

New York Office, 171 Madison Avenue

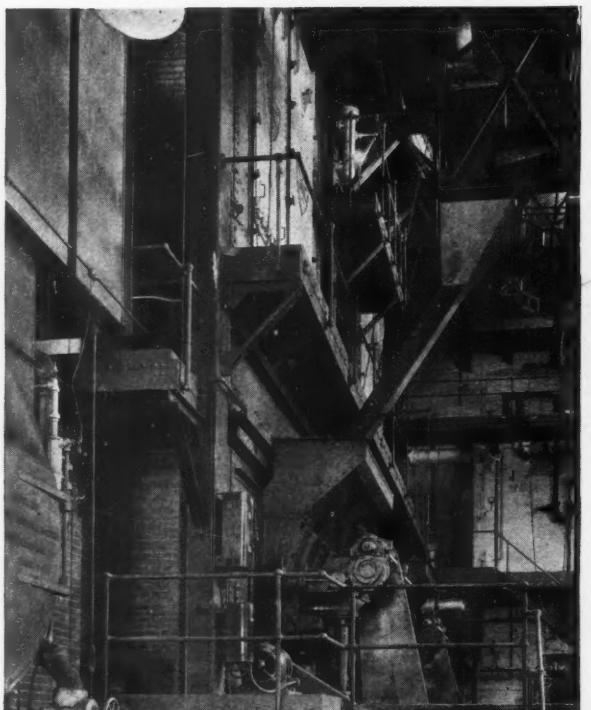
Subscription price: U. S. A. $2 a year; Canada $3.95 a year including duty; other countries $3.50 a year. Single copy current issue: U. S. A. 15c, other countries 25c; except January 1st issue U. S. A. 50c, other countries 60c. Single copy back issue: U. S. A. 25c, other countries 35c; except January 1st issue U. S. A. 75c, other countries 85c.

Member, Associated Business Papers, Audit Bureau of Circulations.

Circulation of this issue 24,350.

Plant Rehabilitation...

The Way to Economical Operation



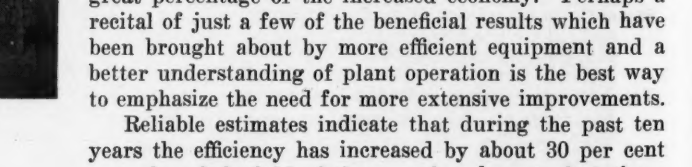
In its definite policy for power plant development, the Champion-International Paper Co. replaced four 110-lb. h.r.t. boilers with two 400-lb. water-tube boilers.

MANY OWNERS of power plants have made the mistake of considering that a plant that was new and modern ten years ago is still new. The heat economy of the plant may still be substantially what it was when the plant was first put into operation; repair and replacement costs may not be excessive; labor costs have not increased and the initial investment is well on the way toward being paid off through the depreciation fund which has been provided. The records indicate that things are substantially as they have been for a long period so the power plant is overlooked in the search for opportunities to economize.

In bewilderment the owner asks "What can we do to save money in our plant?" The answer must come as a result of a careful study of his individual conditions; no general patent medicine type of answer is worthy of consideration. A plant survey analyzing the details of equipment, the plant records, the operating methods, the plant losses and the load requirements must be made and studied in the light of the most modern practice before any sort of recommendation can be made. Piecemeal additions and changes in equipment are advisable only when they fit in with the general rehabilitation plan working towards the future or anticipated needs of the plant.

Progress in equipment and operating conditions in power plants is continuously and definitely reducing the cost of generating steam and electric power. The changes are taking place so gradually and among so many details of power plant equipment that it is only when the total effect is considered that the great progress is noticeable for, during the past decade, there have been no revolutionary developments to credit with any great percentage of the increased economy. Perhaps a recital of just a few of the beneficial results which have been brought about by more efficient equipment and a better understanding of plant operation is the best way to emphasize the need for more extensive improvements.

Reliable estimates indicate that during the past ten years the efficiency has increased by about 30 per cent over the whole field of the use of coal, central stations, industrials, railways and house heating. This remark-



Progress in the reduction of heat units required for power generation at Lakeside Station in Milwaukee is definitely indicated by this curve.

able showing is the direct result of an intensive study of combustion. In the central stations of the country the average amount of coal required per kilowatt-hour of electric energy produced in 1920 was 3 lb. while in 1930 this has been reduced to 1.63 lb., a reduction of 45 per cent.

This progress is definitely indicated by the accompanying curve which was plotted from a record of the Milwaukee Railway & Light Co.'s Lakeside Plant and shows that the heat units required to produce electric energy had been reduced from 21,000 in 1921 to 13,253 in 1931 or nearly 37 per cent. This saving has been accomplished while the plant has been expanding but without replacing of the principal units.

At the Fairfield Blast-Furnace Power Plant power generated from surplus gas per ton of product is about 50 per cent more than it was nine years ago.

Estimates made by Lockwood-Greene Engineering Co. indicate that a certain textile plant of 2500-kw. capacity could save $100,000 a year principally by making use of byproduct power.

By rehabilitating a 2000-hp. plant, the American Thread Co. saved $41,000 or 31 per cent of its yearly operating and fuel costs, which represents 40 per cent on the investment in the improvements.

As a result of a 5-yr. program of improvements on the 1100-hp. plant of the Champion-International Paper Co., a saving of 6000 t. of coal per year has been accomplished.

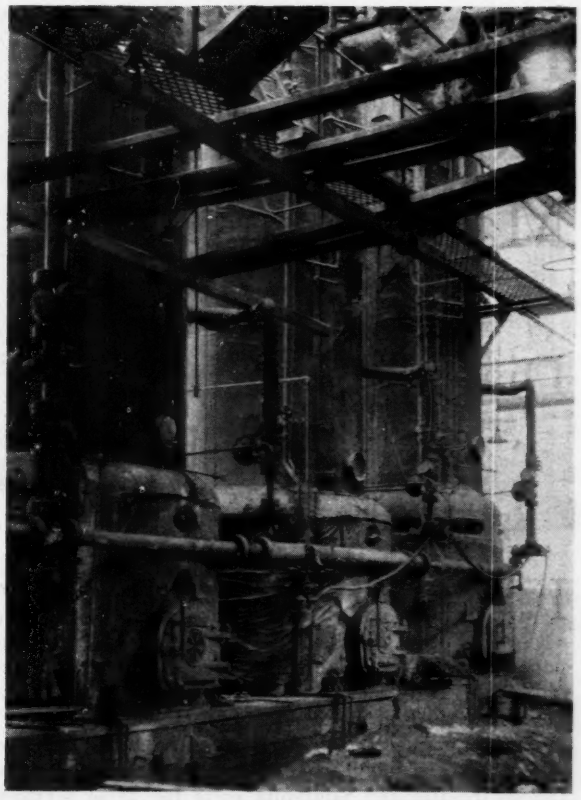
In 1930 the state institutions of Ohio saved $558,875 over previous years as a result principally of more efficient utilization of the more economical sizes and cheaper grades of coal.

Maximum boiler efficiencies obtainable in 1920 were in the neighborhood of 85 per cent while present-day claims range to about 92 per cent. Minimum steam turbine heat requirements for the generation of electric power have been reduced from 12,500 B.t.u. per kw-hr. in 1920 to 8000 B.t.u. in 1930, reduction 35 per cent.

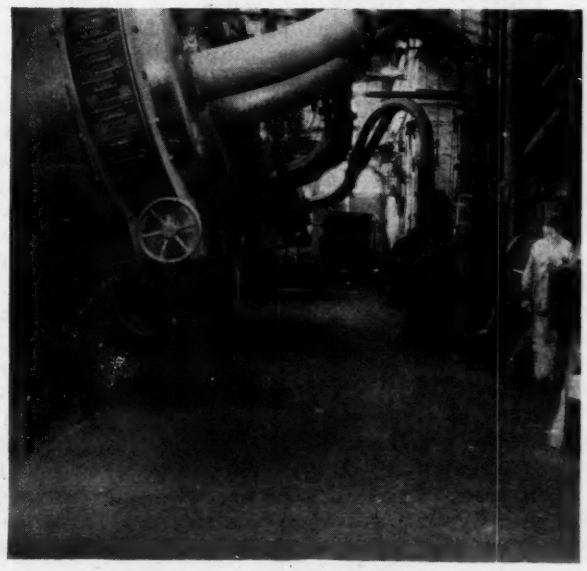
Considering best practice and overall economy, the heat in the fuel required to produce a kilowatt-hour at the switchboard in central stations has been reduced from 16,000 B.t.u. in 1920 to 13,000 B.t.u. in 1930 and in industrial power plants from 28,000 B.t.u. in 1920 to 23,000 B.t.u. in 1930.

Such improved economy is the result of many factors including a better understanding and control of load and service conditions, more economical and reliable equipment, better knowledge of operating conditions through careful selection and use of instruments, wider use of power plant records and, perhaps above all, a more enlightened personnel in the power plant.

As an aid to those who are determined to reduce their power and heating costs to the basis of a strictly modern plant, the information on the following pages has been prepared. The aim has been to outline the procedure by which an engineer can make very definite recommendations for improvements in his power plant and show how and to what extent these improvements will affect the economics of the plant. This study has been set up into four general divisions, namely, a plant survey to determine losses, a study of equipment to determine advancement since 1920, changes in fundamentals of plant practice during the past decade and methods of weighing evidence for and against plant or equipment changes.



In the power plant of the American Thread Co., steam was generated in a battery of 14 boilers of the type shown above but with the installation of water-tube boilers fired by pulverized coal burners as shown below and other important power equipment changes economies amounting to $41,000 a year are reported.

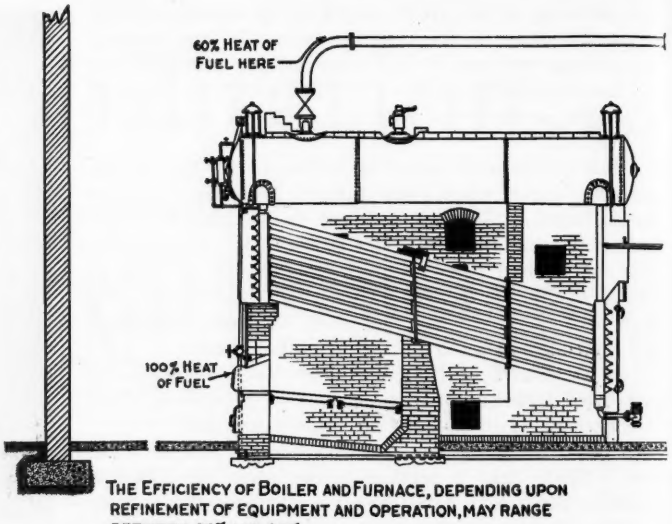


Power Plant Rehabilitation

Making the Survey

Diagnosis and Prescription

By David Moffat Myers



THE EFFICIENCY OF BOILER AND FURNACE, DEPENDING UPON REFINEMENT OF EQUIPMENT AND OPERATION, MAY RANGE BETWEEN 35% AND 84%

IN THE PRACTICE of medicine and surgery, a correct diagnosis must be secured as the first step toward a cure. Otherwise the result may be the death of the patient. When the doctor himself is ill, he calls another physician. He recognizes the need of the outside viewpoint and will take no chances with his own health.

In the engineering problems of industrial steam and power, correct diagnosis is essential to obtaining satisfactory results and minimum costs for these services. Otherwise, while the patient may not die from the subsequent operation, the potential profits may be killed or at least seriously crippled.

It is my experience that the wise resident engineer, and I have many friends among them, when his own plant is ill, like the doctor, also desires the diagnosis and advice of the outside specialist. He feels he is too close to his problem to depend on his own judgment alone; furthermore he is so encumbered with production and maintenance problems that he is unable to devote the requisite time and effort to this highly specialized question.

Power plant engineering compares in a number of ways to the physician's art, with one outstanding advantage, inasmuch as the former can definitely and accurately predict results. Medical treatment and surgery have their counterparts in engineering. If one's health can be made sound without resort to the knife, that is generally regarded as good news. This corresponds in our industrial plant to changing the methods of operation so as to reduce substantially the annual expenses, without the necessity of scrapping old equipment. Many are the plants whose systems have responded nobly to such treatment alone. And many are the owners who, by virtue of skilled diagnosis, have greatly reduced the cost of power, heat and light.

Accurate Analysis

Watching my doctor, I am inclined to regard him almost as a magician in his ability to diagnose quickly and surely. He will take my temperature, feel my pulse, listen to my lungs and heart, make me stick out my tongue, say "aah" and tell me at once I have the grippe. It always seems remarkable that, among all the hundreds of things that might be wrong, he puts his finger squarely on the right spot the first try.

Instinctively, I compare his speed and accuracy of diagnosis with my own and at first feel entirely crushed by the comparison. Then a silver lining begins to show and presently I come to think that engineers are not so bad.

For instance, there was the case of walking through a good sized boiler plant the first day for examination and saying to myself, "If the boilers standing idle were run in place of those being operated, a saving of $15,000 to $20,000 a year could be made." Later after testing and checking, that was recommended to the owner. The change was made and the saving too.

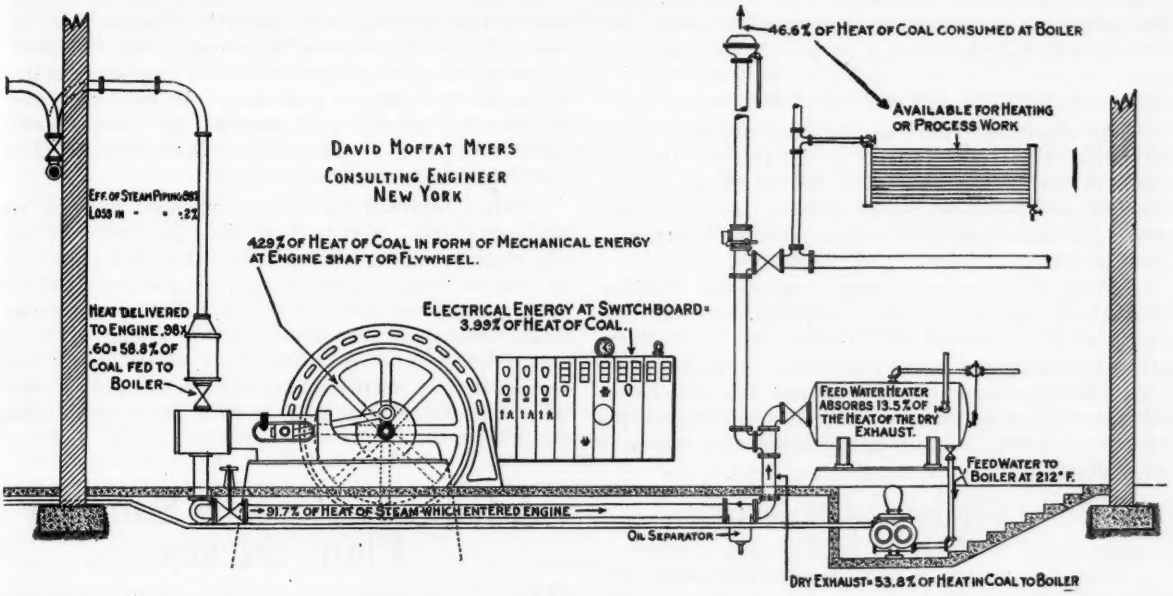
Then there was the case of changing the method of firing of some hand-fired boilers which saved one-third of the fuel. No surgery needed; just right diagnosis and simple treatment.

Another case, we diagnosed and altered the diet of the boilers to a cheaper and more nourishing fuel, saving about a half of their monthly food bill.

In another plant I thought to myself, "A saving of about $20,000 a year can be made by shutting off a certain portion of purchased power and operating two power units now idle." Later, checking by careful cost and engineering analysis, this was confirmed to the owners and the saving was put into immediate effect.

In cases of surgery, or drastic changes in equipment, also by careful review of past instances the engineer specialist approaches the method though he cannot attain quite the speed of the trained physician.

Through contact with numerous cases of all types and kinds, through diagnosis of all the diseases, the doctor learns the symptoms and the necessary checks and tests. The speed with which he reaches his decision seems to the layman like magic. But it is not magic. It is simply that his thorough knowledge of and familiarity with disease develops in him an almost uncanny directness in his methods and he knows what tests and checks to make. The engineer of equivalent skill and practice develops a similar degree of directness in making his findings. One possibility after another is eliminated by certain tests and checks and the most advan-


46.6% OF HEAT OF COAL CONSUMED AT BOILER
AVAILABLE FOR HEATING OR PROCESS WORK
DAVID MOFFAT MYERS
CONSULTING ENGINEER
NEW YORK
EFF. OF STEAM PIPING OR LOSS IN
42.9% OF HEAT OF COAL IN FORM OF MECHANICAL ENERGY AT ENGINE SHAFT OR FLYWHEEL.
HEAT DELIVERED TO ENGINE .98% .60=58.8% OF COAL FED TO BOILER
ELECTRICAL ENERGY AT SWITCHBOARD= 3.99% OF HEAT OF COAL.
FEED WATER HEATER ABSORBS 13.5% OF THE HEAT OF THE DRY EXHAUST.
FEEDWATER TO BOILER AT 212° F.
91.7% OF HEAT OF STEAM WHICH ENTERED ENGINE
OIL SEPARATOR
DRY EXHAUST=53.8% OF HEAT IN COAL TO BOILER

tageous plan for betterment is reached by quite direct methods.

Quantitative Results Demanded

From one important angle the engineer's job is more difficult and more laborious. While the doctor's diagnosis is qualitative, the engineer's work is quantitative. He must not only name the disease and the cure but he must determine the cost and the savings in dollars per year and he must work out the complete economics of his plan before he can give it the rank of a recommendation.

One client, I remember, stood before me with much the same mystified respect with which I am prone to regard doctors. Before diagnosis of the trouble, with all the boilers running and dampers wide open, steam pressure could not be maintained. Now the owner found steam pressure at the popping-off point with half the boilers shut down and the dampers throttled down on the others. The large saving in fuel was an added cause for wonder to the client, though it was of course a simple case of cause and effect to the engineer.

Survey Essentials

One hundred different things can be done in industrial steam and power situations to reduce the cost of these services. I counted up to ninety-nine one day and I am sure of at least one more. The specialist's first aim is, by a suitable survey to determine which of these remedies will produce the best and most satisfactory results, when measured in terms of dollars returned against dollars expended.

Frequently such a survey discovers several plans for improvement. The cost of each plan and its attendant savings must be determined and compared. The choice will then depend upon various conditions including business and manufacturing considerations.

Survey includes an engineering and cost analysis of conditions and requirements. It depends upon facts and facts alone. Guesswork must be eliminated. A complete survey includes analysis of the generation and utilization of steam and of the generation or purchase and use of power. In certain localities the purchase of steam is also included.

Such a survey considers the two comprehensive and complementary phases of operation and design. The over-all result is the product of both. Operation comprises the handling of the human factor; design, the layout and specification of mechanical equipment. A given plant's expenses may often be reduced from 10 to 40 per cent without altering its mechanical equipment, by bringing the methods of operating the plant up to a proper standard.

Heat Balance Study

Complete survey always considers heat balance, all the way through from the purchase, handling and combustion of the fuel to and through the generation and purchase or purchase alone of power and the economical distribution and utilization of heat and power throughout the plant. The most effective use of exhaust steam at various pressures is an intrinsic part of this study.

Illustrated in the headpiece is a heat balance in an industrial power plant. This was designed as a key to a proper study of existing conditions and to make clear the cycle of heat generation, distribution and expenditure. At each point of the cycle is the possibility and likelihood of preventable waste. Location and extent of each unnecessary loss must be determined by the survey; then suitable means must be recommended for changing these losses into savings.

Facts comprise the foundation of the survey. Suitable calibrated instruments must be depended upon for securing and recording the physical data to give these facts. In some plants it is harder to secure the facts than in others. In any plant where essential operating data is lacking will inevitably be found large preventable waste.

A nationally-known industrial plant, which recently called us in to make a survey, had no operating data whatever,—no records of coal, or of evaporation of steam, or of electric power used,—nothing but the monthly bills for material and labor. Why the bills were

so large of course no one knew. But, when the facts were found and records made, the waste was found and the cure determined.

Competent Judgment Is Essential

To be of greatest value, a plant survey must be made by engineers not only capable of determining the efficiency of the existing equipment but who know all the possibilities and efficiencies of present day steam and power equipment and how to apply it for the greatest practical value.

Seldom does central station engineering practice apply in the industrial plant. This does not mean that purchased power should not be used; on the contrary, advantages of buying power are great in many instances. But, it does mean that the design of an industrial power plant must be tailor-made to fit the special requirements for process steam and power, which differ so widely in every plant.

Present Conditions Are Opportune for Rehabilitation

Today the country is teeming with sick plants and never before has medicine been so cheap. Modern, efficient steam and power equipment can be bought at bargain prices which may not remain long at these low levels.

Even when prices were high, properly prescribed improvements would pay back their cost in a very reasonable time. Today the return on the investment is greatly enhanced. The cost of a modern boiler plant today approaches half of its cost 2 yr. ago.

Owing to recent improvements in steam and power apparatus, and to their present low cost, every industrial power plant which is 10 yr. old should be investigated now. Many items not apparent on the surface of the heat balance, have a vital effect on power plant economy and all of these should be considered in a survey. These items are commercial values.

Frequently, where all the power is purchased, there is a tendency to neglect the boiler plant. This results in a wastefully high cost of steam.

For instance, without changing the efficiency of the boilers it is common to find a fuel which will produce cheaper steam. Again, frequently, the further use of purchased power will reduce over-all cost, although often the reverse is the case.

In many cases, metering of steam and power to departments discovers large consumption without corresponding production and gives opportunity for direct, quick savings.

In some cases, we have been able to shut down boilers and even whole boiler plants, where a steam line from a more efficient boiler or plant takes their place. Then there is the widening opportunity for making by-product power from process steam due to the higher pressure boilers and turbines now available.

Again, there is a distinct field for Diesel engine power, sometimes in combination with steam-driven units, which is capable of yielding heat and dollar economy.

Where electric power is purchased, much can be done to reduce the power bill by taking full advantage of the contract. Such improvements depend on betterment of the power and load factors and use of off-peak power.

In short, the improvement possibilities in a plant involve both thermal and commercial values. The one hundred possible items for improving steam and power situations must be understood by the engineer engaged in the survey. Like the good doctor, he must accurately diagnose the trouble and prescribe the most effective cure. Each power problem must be individually studied. As in medicine, there is no cure-all.

Dollars returned for dollars expended measure the engineer's work. Net profit to the plant owner is usually much greater compared to cost than that obtainable by similar sums expended on increased sales efforts. With the present abnormally low cost of power equipment, owners and managers will soon belong to the "I wish I had" club unless they take advantage of these savings now so readily within their reach and seriously undertake the rehabilitation of their power and heating facilities.

Adequate Records Simplify Plant Survey

TO AID the engineer in making a survey of a plant for rehabilitation purposes, nothing is more helpful than a well-kept record of the plant dating back to the installation of the equipment. Lacking such a record, the engineer must devise some means for finding out the condition of the present equipment so that it may be compared with the best modern equipment available. The most common and convenient records may usually be classed under one of three classes, namely: Equipment, Operating and Cost.

Records of Equipment

Equipment records are of particular value when changes are contemplated for, when properly kept, they give a complete detailed history of each piece of equipment in the plant with all the troubles that have been encountered, the repairs and replacements that have been made, the initial and additional costs from installation to date, the hours in service and the load carried. Some form of ledger system is probably the most convenient as it can be arranged in concise form with an account entered against each principal unit in the plant, the attached mountings and individual auxiliaries being considered as part of the unit. With this data in hand and kept up to date, the turning point when the equipment should be replaced can quickly be determined.

Plant Operation Records

To those in charge of plant operation, another form of record is required. The problem of these engineers is to secure the highest efficiency possible in the operation of existing equipment. It involves the establishing of a standard set of controllable conditions for each set of uncontrollable conditions which the plant may be called upon to meet, then maintaining the standard best suited to the existing conditions. Among the conditions not usually under control of the operating force are atmospheric conditions, condensing water temperature, chemical condition of raw water, exact quality of fuel, electric load curve, demand for process and heating steam and other services rendered to departments outside the power plant.

As all these conditions sometimes change quite rapidly, the ideal operating record should be continuous where possible as with graphic recording instruments. Where this is impossible, readings recorded every 15 min. or half hour by the attendant have been found of great value. The accuracy with which the operating force is able to meet changing conditions promptly has much to do with the economy obtained and a study of the operating record is of great aid to the engineer in determining the extent to which equipment changes should be made or the personnel instructed.

Low Costs Are Essential

Power plants are essentially money-making or money-saving investments; as such the cost of operation must be kept as low as possible consistent with safety. Cost records are therefore of most importance to the plant owner. He is interested in knowing the overall plant cost and how it varies from week to week and month to month. To show causes of variation, unit costs are quite essential, they also help in determining whether to generate or purchase services required by the factory. All these costs should be available to the engineer making a study of a plant for rehabilitation purposes, as it is upon the cost basis that all changes should be made.

Instruments Required in Study of Plant Condition

INSTRUMENTS are installed in power plants for two general purposes, namely, to aid in the determination of unit costs and to indicate physical and chemical conditions, the number and selection being determined for each individual plant according to the particular needs.

For the determination of unit costs, the instruments required are principally of the weighing and measuring type which integrate or record weights or quantities of such supplies and products as fuel, water, steam, power, air. These must be supplemented by instruments that give the conditions of these products—temperatures, pressures, densities, chemical analysis—which will enable the engineer to reduce his products to equivalent terms. The minimum number of these instruments which any plant should install is that required to determine the overall efficiency of the plant and the unit costs of products each day of operation from data recorded in the log sheet.

The number of instruments could, of course, be increased to the extent that the efficiency of each unit may be determined from the daily log. Usually, however, the engineer takes the middle ground in his selection and equips his plant with sufficient instruments to determine the overall efficiency of each step in the plant —steam generation, electric generation, electric switching and transformation, pumping and heating service water, air compression, refrigeration—from the daily record and when any section of the plant fails to meet the standard set for it, the various units in that section are given special consideration. For this purpose, temporary or portable instruments are used to supplement those already installed. The efficiency here is considered as the output divided by the input, both quantities, of course, being expressed in the same equivalent terms.

Instruments That Aid in Plant Operation

Plant efficiency is the result of a combination of maintained conditions, a variation in any one of which will cause others to change. So it behooves the engineer in charge to ascertain through tests the most efficient controllable conditions to maintain under the varying load conditions of the plant. While the instruments used in the determination of costs and efficiencies are all helpful to the operator, they are not sufficient to determine exactly what condition is varying from the standard established nor to guide the operator in his work.

It is advisable, therefore, to provide as regular equipment such instruments as the following:

Thermometers or temperature indicators—in the feedwater line at places where temperature changes take place; fuel oil line; flue gas passages; combustion air duct; steam piping system; condenser, steam and water sides; main engine and turbine bearings; generator coils; transformer oil and circulating water.

Draft gages—throughout boiler settings.

Pressure gages—important points in water, steam and compressed air lines.

Vacuum gages—pump suction lines; condenser steam space; vacuum heating lines.

Level indicators—water tanks; receivers; boilers.

Flow meters—water, steam, air lines.

Combustion control instrument on boilers.

Ammeters, voltmeters, wattmeters—on generators and various circuits.

To make a survey of a plant, often the regular installed instruments must be supplemented by portable instruments found necessary to determine some specific condition of the equipment, a study of which is found advisable. A plant equipped with a sufficient number of the following instruments having the proper ranges should be well fitted to carry out the necessary tests of equipment.

Ammeters, barometer, calibrated tanks, chemical analysis instruments for analyzing fuel, water, oil and flue gases, draft gages, dynamometer, engine indicator, fuel calorimeter, hydrometer, manometer, megometer, mercury column, orifice nozzles, pilot tubes, planimeter, platform scales, pressure gages, psychrometer, speed indicator, steam calorimeter, stop watch, thermometers, vacuum gages, voltmeters, wattmeters.

Determination of Tests to Be Made

REHABILITATION usually comes as a result of changes in the load or service conditions imposed upon the plant; either the plant has been found inadequate to meet the present conditions or it is realized that the contemplated changes in service will require changes in power plant equipment. Usually the need is quite evident before any changes whatever are considered and the plant equipment is so obsolete that the owner is incurring a heavy needless expense when the engineer is instructed to determine what improvements are needed to meet the present and expected demands.

The plant records, if they have been adequate and properly kept, will point directly to the part of the plant which is costing more to operate and maintain

than it did when first installed. The most outstanding cases should receive first consideration to determine the causes. It may be found that a thorough overhauling will bring the equipment back to its former best condition. Parts subject to wear are usually so designed that they may be replaced at moderate expense. Corrosion cannot always be anticipated as definitely as erosion and an examination may reveal replacement of parts necessary on account of this. Following a thorough examination of the equipment, the cost of placing it in first class condition should be carefully determined before actual work is started, as it may be found that the overhauling will cost as much as new modern equipment better suited to the conditions.

It is imperative, therefore, to become familiar with the possibilities of the installed equipment and that available on the market, so that direct comparisons can be made, particularly as to efficiency, capacity, reliability and safety.

Operating efficiency is, of course, extremely more important than the efficiency obtained during a specially made test. If the records of plant operation contain the necessary information for determining efficiency, they should be used in preference to test data but where tests are necessary, the operating force should use the same degree of care to maintain conditions as in every day operation. After preliminary tests are made and results studied, it may be found that changes in operating methods will increase economy. The most important efficiency tests have to do with boilers, generating units, pumps, draft fans and principal auxiliary drives. The units should be subjected to test separately as overall efficiency is of little value in eliminating losses.

Capacity tests are essential where load changes are taking place or are contemplated. As a rule, they must be specially made as the operating load cannot usually be varied to such an extent as to load the unit at the minimum and maximum of its range and hold it there long enough to obtain reliable results.

Reliability of equipment is an extremely important factor in power plant operation and yet it is the most difficult to determine in advance of failure of the equipment. Equipment may be weakened and liable to break due to wear, erosion or corrosion and inspection should include examination of such parts as are subject to these defects. If at any time in the past repairs or replacements have been made, the parts affected should be examined with care. The records of the plant should show the cause of outage of all principal equipment and by removing these causes, the reliability of the units should be increased.

With contemplated increases in load, it is quite important to run endurance tests at maximum capacities on such equipment as steam generating units, electric generators, motors and transformers, as such tests will reveal weak points in the system. It may be in the fuel handling or firing equipment, furnace walls or draft system, the method of combustion control or water treating system. An endurance test should be run with extreme care and changing conditions studiously observed so as to prevent serious trouble. When defects begin to show up, they are likely to occur in the least suspected places.

Safety is of paramount importance and in a survey of a plant all dangerous conditions should be carefully noted and rectified. Equipment that is likely to break down during operation, cause an uncontrollable fire or explosion, or injure an operator using ordinary care in his work is not safe and the condition should be rectified.

Usually it is some detail of equipment that fails to function properly and puts a unit out of operation. Often replacing some such device as control equipment or defective valve will put an important unit in first class operating condition. In a survey, therefore, each piece of auxiliary equipment or mounting should be examined and caused to operate under practical conditions while under observation. The slightest failure to function properly should be followed by a thorough test through its entire range of service.

Heat Balances of 1920

CENTRAL STATIONS AND INDUSTRIAL PLANTS USED ECONOMIZERS, SOMETIMES EXTRACTION TURBINES FOR FEEDWATER HEATING OR PROCESS STEAM, BUT IN GENERAL THE HEAT BALANCES WERE SIMPLE

HEAT BALANCES of 1920, as compared with those of today, were comparatively simple. Steam flowed from boilers to engines or turbines; in the central station, it exhausted at high vacuum to the condenser, in the industrial plant to condenser or exhaust steam heating system or to process steam systems, steam not used in these being often employed to heat feedwater. There were installations of Diesel engines, of course, but there was little interest in reclaiming heat from exhaust gas or jacket water. In steam plants practically the only device used generally for trapping waste heat in the flue gas was the economizer. Air preheating had been experimented with for years but was not often used in boiler plants, primarily because the combustion conditions it produced were too hard on furnace brickwork.

Extraction feedwater heating or the regenerative feedwater cycle, as it was sometimes called, was infrequently used in central stations in 1920. Extraction of steam between cylinders of a cross-compound engine or from a turbine stage for process work or heating was sometimes practiced in industrial power plants and occasional layouts are found in which it was also used for feedwater heating. The feedwater heater using steam at atmospheric pressure was the most common method of heating boiler feedwater. Occasionally, however, a central station was designed with one closed feedwater heater taking steam extracted from the turbine, in addition to the usual open heaters and sometimes deaerators were employed but such stations represented advanced practice at that time and were exceptions to the general rule.

CENTRAL STATION HEAT BALANCE OF 1920

In such layouts, steam-driven auxiliaries were a greater necessity than they are today for providing steam to maintain proper heat balance conditions by

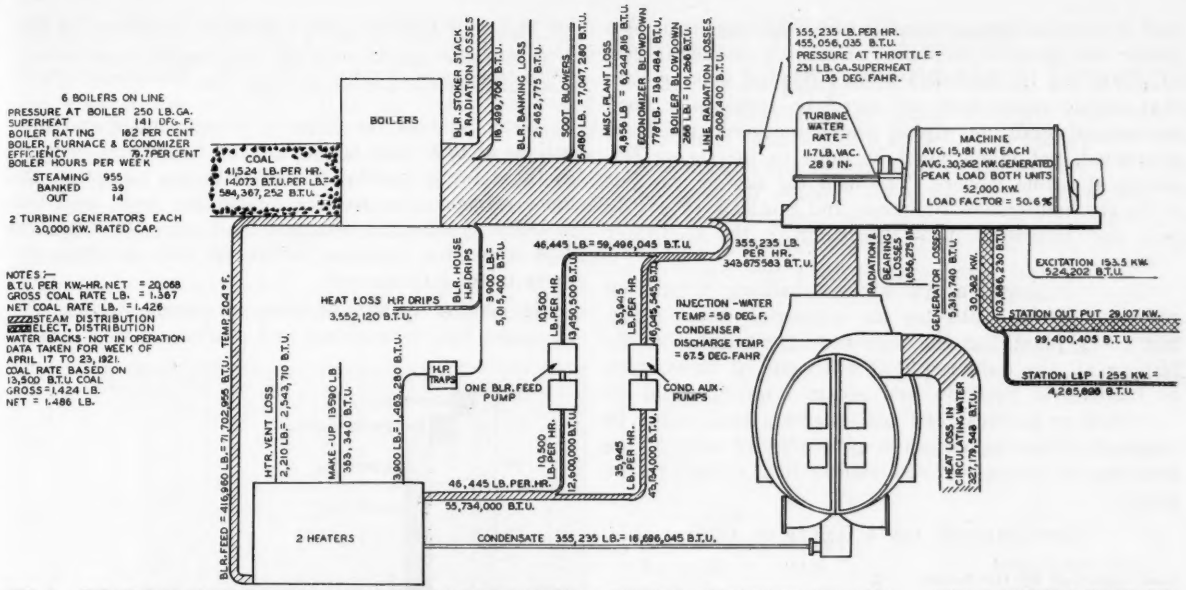

6 BOILERS ON LINE
PRESSURE AT BOILER 250 LB. GA.
SUPERHEAT 141 DEG. F.
BOILER RATING 162 PER CENT
BOILER, FURNACE & ECONOMIZER EFFICIENCY 79.7 PER CENT
BOILER HOURS PER WEEK
STEAMING 955
BANKED 39
OUT 14
2 TURBINE GENERATORS EACH 30,000 KW. RATED CAP.
NOTES:-
B.T.U. PER KW.-HR. NET = 20,068
GROSS COAL RATE LB. = 1.387
NET COAL RATE LB. = 1.426
STEAM DISTRIBUTION
ELECT. DISTRIBUTION
WATER BACKS NOT IN OPERATION
DATA TAKEN FOR WEEK OF APRIL 17 TO 23, 1921.
COAL RATE BASED ON 13,900 B.T.U. COAL
GROSS = 1.424 LB.
NET = 1.486 LB.
BOILERS
COAL
41,524 LB. PER HR.
14,073 B.T.U. PER LB.
584,367,252 B.T.U.
BLR. STOKER STACK & RADIATION LOSSES
BLR. BANKING LOSS
2,482,775 B.T.U.
SOOT BLOWERS
MISC. PLANT LOSS
ECONOMIZER BLOWDOWN
BOILER BLOWDOWN
LINE RADIATION LOSSES
2,009,400 B.T.U.
355,235 LB. PER HR.
455,056,035 B.T.U.
PRESSURE AT THROTTLE = 231 LB. GA. SUPERHEAT 135 DEG. FAHR.
TURBINE WATER RATE = 11.7 LB. VAC. 28.9 IN.
MACHINE
AVG. 15,181 KW EACH
AVG. 30,362 KW. GENERATED
PEAK LOAD BOTH UNITS 52,000 KW.
LOAD FACTOR = 50.6%
46,445 LB. = 59,496,045 B.T.U.
355,235 LB. PER HR. 343,875,583 B.T.U.
RADIATION & BEARING LOSSES 656,275 B.T.U.
GENERATION LOSSES 5,313,740 B.T.U.
30,362 KW. 103,646,230 B.T.U.
EXCITATION 193.5 KW. 524,202 B.T.U.
STATION OUT PUT 29,107 KW.
99,400,405 B.T.U.
STATION L&P 1,255 KW. = 4,285,600 B.T.U.
BLR. HOUSE H.P. DRIPS
9,900 LB. = 5,015,400 B.T.U.
HEAT LOSS H.P. DRIPS 3,552,120 B.T.U.
10,500 LB. PER HR. 13,450,500 B.T.U.
35,945 LB. PER HR. 46,048,343 B.T.U.
INJECTION - WATER TEMP = 58 DEG. F.
CONDENSER DISCHARGE TEMP. = 67.5 DEG. FAHR.
H.P. TRAPS
ONE BLR. FEED PUMP
COND. AUX. PUMPS
HTR. VENT LOSS 2,210 LB. = 2,543,710 B.T.U.
MAKE-UP 13,580 LB. 365,340 B.T.U.
3,800 LB. = 1,483,280 B.T.U.
10,500 LB. PER HR. 12,600,000 B.T.U.
35,945 LB. PER HR. 43,134,000 B.T.U.
HEAT LOSS IN CIRCULATING WATER 327,179,548 B.T.U.
46,445 LB. PER HR. 55,734,000 B.T.U.
2 HEATERS
CONDENSATE 355,235 LB. = 16,696,045 B.T.U.
BLR. FEED = 416,980 LB. = 7,702,956 B.T.U. TEMP. 204 DEG. F.

FIG. 1. HEAT BALANCE DIAGRAM FOR ONE OF THE BEST CENTRAL STATIONS OF 1921. ITS PERFORMANCE IS MUCH ABOVE THE AVERAGE OF ALL STATIONS OF THAT PERIOD

heating feedwater. The accompanying typical heat balance and heat loss diagrams show this point clearly. Figure 1 is the heat balance diagram for one week's operation of a central station containing two 30,000-kw. units operated during this particular week, however, with an average load of 30,362 kw. and average vacuum of 28.9 in. Under these conditions the station heat rate is 20,068 B.t.u. per net kw-hr. Operating with a load of 44,000 kw. this station showed a heat consumption of 17,982 B.t.u. per kw-hr.

Industrial plants in 1920 were seldom equipped to make studies of heat balance as detailed as those shown above. There was much interest in the general subject of power economy, however, and considerable information had been accumulated to show the average heat losses that might be expected in various equipment and the losses that probably were unavoidable. Figures 3 and 4 show some of the factors that were considered in attempting to eliminate avoidable losses.

Economizers were recommended for reducing some of the stack loss and transferring the reclaimed heat to the feedwater, exhaust steam from engines and pumps was used for feedwater heating and exhaust steam for processes and heating systems was suggested as an effective means of utilizing heat that might otherwise be wasted. Care was urged in returning condensate to the hotwell, to clean it of oil and to use it again as boiler feedwater.

Industrial Plant Heat Balances of 1920

In making up the heat balance of the average industrial plant of 1920, most attention was concentrated on the analysis of losses in steam generation and in taking measures to prevent them. It was becoming apparent

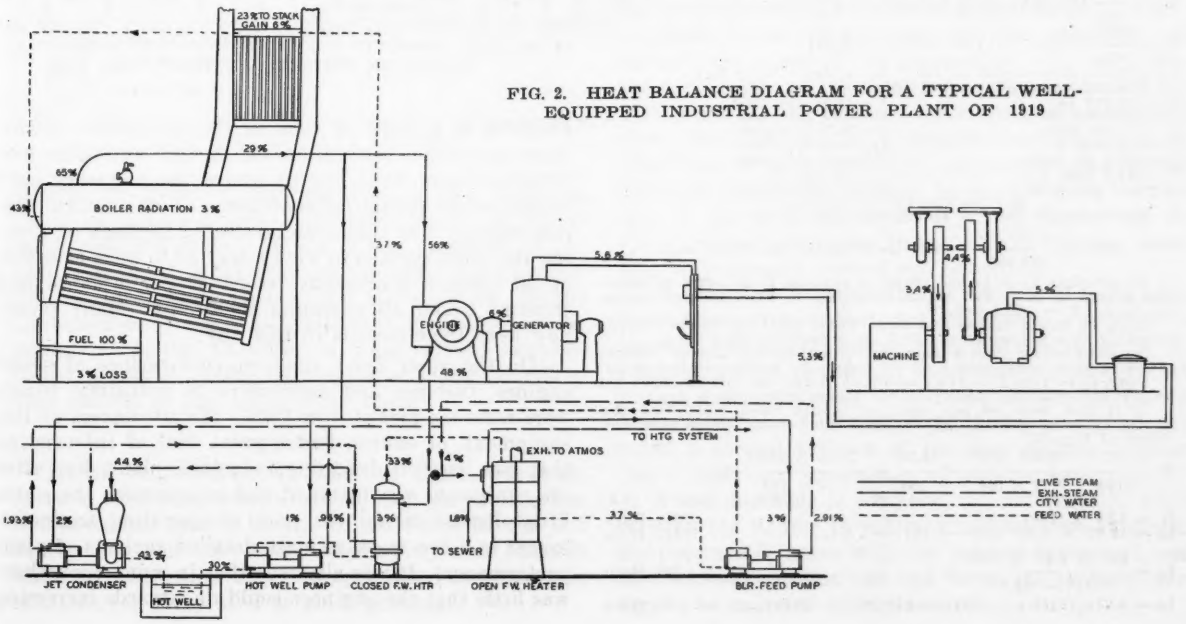


FIG. 2. HEAT BALANCE DIAGRAM FOR A TYPICAL WELL-EQUIPPED INDUSTRIAL POWER PLANT OF 1919

that in most industrial plants which generated their own power, the greatest possibility of making savings in cost of power lay in the boiler room. Beyond making sure that engine valves were set correctly, turbines in good mechanical condition, piping properly covered and leaks prevented, not much could be done in increasing efficiency of prime movers. The field for saving was felt to be the combustion processes and methods of saving heat and returning it to the boiler in the feedwater heater.

Below is shown a typical heat balance calculation recommended in 1919 for an industrial boiler plant. Not every plant had the requisite instruments for obtaining all the data required but some of these, such as barometric pressure and steam quality, could be estimated or assumed and coal analyses could often be obtained with some accuracy by averaging some of the government analyses of coal similar to that used in the plant.

Heat Balance for a Boiler in 1920

Item and symbol		B.t.u.	%	$
Heat absorbed by the boiler	E			
Dry flue gas loss	L_1			
Unburned carbon loss	L_2			
Loss from moisture in coal	L_3			
Loss from burning hydrogen	L_4			
Radiation and unaccounted for	L_5			
B.t.u. commercial and coal bill				
			100	

Heat Balance Data

Total coal pounds, B.
Total water pounds, J.
Average CO_2, G.
Average stack temperature, T.
Actual evaporation, J/B.
Average steam pressure, gage, P.
Average feedwater temperature, F.
B.t.u. in one pound of steam at P+barometer and from F, D.
Ash, commercial, A.
Unburned carbon, Y.
Moisture, M (in coal).
Total carbon in the coal, C.
Hydrogen in the coal, H.
Nitrogen in the coal, N.
Total dry products of combustion per pound of coal, W.
Temperature of the air entering the furnace, t.

Instructions for Figuring the Heat Balance

$E = J/B \times D$

$L_1 = W \times 0.237\ (T - 70)$

$L_2 = \dfrac{145 \times A \times Y}{100 - Y}$

$L_3 = \dfrac{M}{100}\ [(1182.4 - t) + 0.46\ (T - 212)]$

$L_4 = \dfrac{9XH}{100}\ [(1182.4 - t) + 0.46\ (T - 212)]$

L_5 = B.t.u. commercial — $(E + L_1 + L_2 + L_3 + L_4)$.

Practical example worked out:

B—480,000 lb.	Y—18.67 per cent.
J—4,290,000 lb.	M—3.60 per cent.
G—10 per cent.	C—78.76 per cent.
T—570 deg. F.	H—4.47 per cent.
P—125.0 lb. gage.	N—1.35 per cent.
F—192.8 deg. F.	t —70 deg. F.
A—7.21 per cent.	B.t.u. commercial—14,148.

Barometer—14.7 lb. per sq. in.

Three things must be computed—J/B, D, and W.

$$J/B = \frac{4{,}290{,}000}{480{,}000} = 8.94 \text{ lb. of water per lb. of coal.}$$

To compute D, it is necessary to express P in terms of absolute pressure: P + 14.7 = 125.0 + 14.7 = 139.7 lb. per sq. in. absolute. F = 192.8 deg. F.

Turn to steam tables and find "Total Heat of Steam" corresponding to a presssure of 139.7 lb. Answer—1192.2 B.t.u.

Turn to steam tables and find "Heat of the Liquid" corresponding to a temperature of 192.8 deg. F. Answer—160.7 B.t.u.

Then D = 1192.2 — 160.7 = 1031.5 B.t.u. In this example we have considered the quality of the steam to be 100 % dry.

If it had been 98 per cent we would have multiplied the "Total Heat of Steam" by 98 per cent before subtracting the "Heat of Liquid."

$$W = \frac{C}{100} + \frac{243.6 \times C}{G \times 100} = \frac{78.76}{100} + \frac{243.6 \times 78.76}{10 \times 100} =$$

$$0.7876 + 19.18 = 19.97$$

$E = 8.94 \times 1031.5 =$ ..... 9224 B.t.u.

$L_1 = 19.97 \times 0.237\ (570 - 70) =$ ..... 2367 B.t.u.

$$L_2 = \frac{145 \times 7.21 \times 18.67}{100 - 18.67} =$$ ..... 240 B.t.u.

$L_3 = 0.036[(1182.4 - 70) + 0.46(570 - 212)]$..... 46 B.t.u.

$L_4 = 9 \times 0.0447[(1182.4 - 70) + 0.46(570 - 212)]$.... 514 B.t.u.

$L_5 = 14{,}148 - (9224 + 2367 + 240 + 46 + 514)$.....1757 B.t.u.

If the reader wishes to see what these figures are in per cent, divide each one of the B.t.u.'s by 14,148. The total of the per cents obtained this way should equal 100.

Heat balances for office buildings, hotels and institutions in 1920 were much the same in general principle as those for industrial plants, with the exception that more refrigeration and fan ventilation were used than in industry, also the demands for steam, hot water and cold water for kitchens, bathrooms and laundries had to be taken into account.

In making up heat balances of central stations, performance data on turbines and condensers were usually

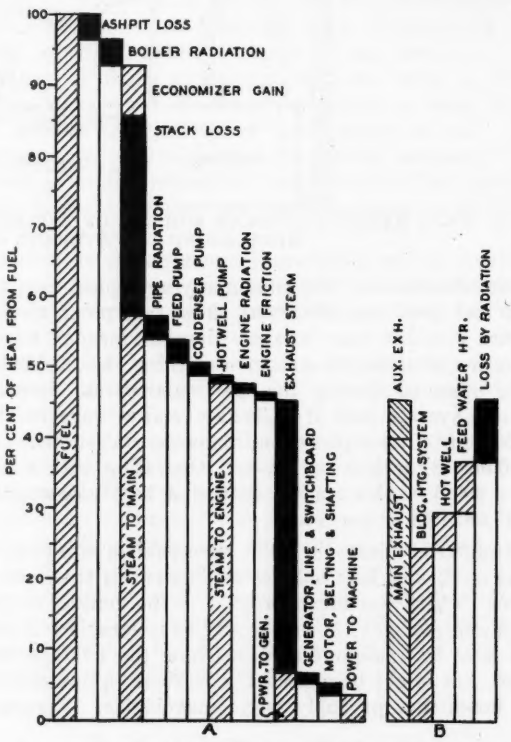


FIG. 3. A—TYPICAL THERMAL EFFICIENCY CHART OF 10 YR. AGO. LOSSES IN BLACK. B—HOW EXHAUST STEAM COULD BE UTILIZED AT THAT TIME

available as a result of tests on the equipment. Sometimes acceptance test data could be used and often performance tests were run to secure the necessary data under actual operating conditions. Some central station engineers at that time advocated methods of keeping the plant records in such a way as to have available at all times a continuous record of performance and economy under all operating conditions. Many plants now keep their records in this way.

On the other hand, data on performance of steam engines, turbines and condensers in industrial plants were none too plentiful in 1920. Manufacturers of this equipment, of course, had a great deal of information that was used in designing industrial plants but after the equipment was installed and in operation there was little disposition on the part of operating engineers, except in a few cases, to make detailed analyses of plant performance. It was also true that in many cases there was little that the engineer could do towards increasing

the efficiency of his prime movers after they had been installed. Furthermore, since in many industrial plants the prime mover exhaust was used for heating or process work it was considered that the power was being made principally as a by-product and that as long as steam was wasted to the atmosphere only during the summer, the overall efficiency of the plant was high. In some cases, condensers or water heaters were used to take excess exhaust steam and sometimes extraction turbines were employed. For the most part, however, attempts to prevent losses in the power generating section of the plant were confined mostly to insuring con-

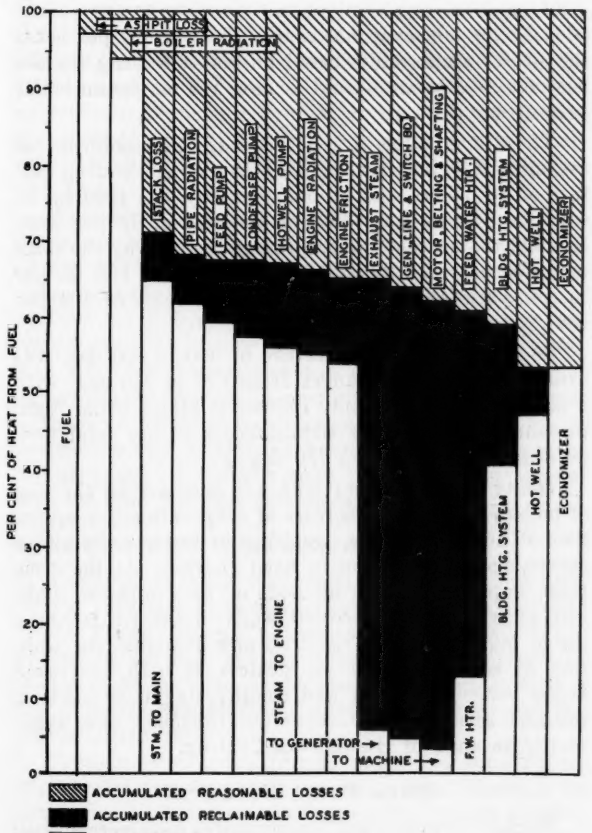


FIG. 4. CHART MADE 10 YR. AGO TO SHOW REASONABLE AND UNNECESSARY LOSSES

tinuity of operation, freedom from steam leaks and excessive radiation losses and maintenance of proper mechanical conditions. When it was necessary to balance heat input in the coal against losses and heat output of the prime movers, the results were usually expressed as so many kilowatt-hours, pounds of steam, pounds or gallons of water or other services supplied to the processes by the burning of so many pounds of coal, gallons of fuel oil or other units.

MAXIM SILENCER CO. of Hartford, Conn., has established a consulting service, specializing on noise reduction problems, headed by Dr. Hiram Percy Maxim and having available the entire engineering and research staffs. It will utilize 20 yr. of specialized experience in solutions for every kind of noise problem.

Losses With Present Equipment and Practice

TO IMPROVE power plant economy, more can be learned from a study of the losses encountered than from the efficiencies obtained. In the survey of a plant, therefore, all possible losses should be listed and the importance of each determined. This data should be obtained from the operating records, tests run under

FORM FOR LISTING AND COMPARING LOSSES

List of Power Plant Losses	Losses in B.t.u. Equivalent		
	Operating Results	Test Results	Possible Results With New Equipment
Boiler - overall			
Ashpit			
Radiation and unaccounted			
Stack			
Moisture and hydrogen			
Safety valve			
Blowoff valve			
Soot blowers			
Carbon monoxide			
Turbine or Engine - overall			
Radiation			
Friction			
Exhaust Steam			
Generator			
Switchboard			
Transformer			
Steam Piping - overall			
Radiation			
Friction			
Auxiliaries			
Feedwater heaters - Radiation			
Boiler feed pumps - Power to drive			
Condenser pumps - Power to drive			
Draft fans - Power to drive			
Stoker drives - Power to drive			
Exciters Power to drive			
Coal and ash handling - Power to drive			

operating conditions and the heat balance studies.

In listing the losses, it is well to tabulate their values as obtained in operation either in per cent of power generated, where power is the sole product of the plant, or in equivalent B.t.u. where the plant furnishes power, heat, water, compressed air and other services. In another column list the values obtained from tests run under best possible conditions. In a third column, list the losses with strictly modern equipment.

Careful study of this table and the equipment will indicate the extent of the preventable losses with present equipment and the betterment anticipated with new equipment. If the value in column one is considerable more than in column two, it is quite likely that operating conditions or load factors are not properly maintained and corrections can be made by more definite instructions to the operators. Often it will be found that the operators need additional instruments to indicate conditions or automatic control equipment.

If the items in column three are less than those in column two, it is evident that the present equipment is obsolete and if the difference is sufficiently great the engineer will be justified in recommending replacement. Such a recommendation relative to a principal unit is likely to affect other equipment in the plant and will entail a careful revision of the heat balance diagram and a study and comparison of possible hookups.

When this table is complete, the difference in value between the figures in columns one and two represent the preventable losses with the present equipment, and that between columns two and three, the probable savings to be expected by replacement.

Ten Years of

Progress in Power Equipment

With the advent of higher steam pressures and temperatures in power plant practice came the need for special metals and redesigned equipment and auxiliaries. These practices and materials have resulted in higher efficiencies, lower fuel and labor costs, reduced space requirements, increased availability of equipment.

WHEN THE PROBLEM of modernizing a power plant is approached, one of the first studies to be made is the possibilities of manufactured equipment available today as compared with that installed in the old plant. That efficiencies have been increased in nearly every class of equipment nobody would doubt; the exact amount, however, is the question in which the engineer is interested. That the element of human operating skill enters less in power plant operation today than it did 10 yr. ago is due to the development of automatic control, much of which can be used to advantage in increasing the efficiency of older types of equipment. That lower grades of fuel can now be used to advantage than a decade ago is common knowledge; what this may mean in dollars and cents to a particular plant is a problem for the engineer charged with the responsibility of rehabilitation.

During the period following the World War, as probably never before, engineers have followed closely the discoveries of scientists and built their equipment on more scientific lines than before with the inevitable result of simpler, safer and more efficient machinery. Many industrial laboratories have been established and a great amount of coöperative scientific work has been carried out. The physicist, chemist and mathematician have been called in on equipment development problems and their solutions are available for industrial use. How they have affected the economy of power plant operation is a study each engineer should conduct in his plant.

Coal Handling Equipment

Much has been learned since 1920 about outside coal storage, prevention of combustion and deterioration and handling in and out of storage. Equipment has been improved mechanically and a new type of drag scraper has been extensively used. Silos have been used frequently for coal storage, also to replace inside coal bunkers. Elevating and conveying equipment has made extensive use of anti-friction bearings and pressure lubrication and there have been many improvements in mechanical construction. Skip hoists have been more extensively used for handling both coal and ash. For all types of conveying equipment, control devices such as stops, interlocking devices, automatic skip hoist controls and the like have been developed. Ash handling methods have been improved and the sluicing system has found many applications for this, in addition to skip hoists, steam jet conveyors and mechanical conveyors.

It is difficult even for those intimately connected with the industry to realize the tremendous strides that have been made in the boiler room during the past decade. Boiler efficiency has increased about 10 per cent; the size of single units based on boiler heating surface has increased about sixfold as have the maximum boiler pressures.

These maximums are not perhaps as significant as averages. For instance, in 1920 the average heating surface of all boilers sold by one company was 4340 sq. ft. while in 1930 it was 7480, an increase of 73 per cent. In 1920 the average boiler pressure as sold by the same manufacturer for all types of service was 162 lb. per sq. in. while today it is 332 lb. an increase of 104 per cent.

In 1920 a total temperature of 400 to 500 deg. was usual while today it ranges from 600 to 850 deg. with a peak of 1000 deg. Many industrial plants using high-pressure boilers find it advantageous to use total temperature of from 700 to 750 deg. F.

Going hand in hand with the increase in the size of boilers has been an increase of evaporation per square foot of heating surface, resulting in fewer units and a corresponding reduction in fixed charges. At the same time, improvements in methods of fuel burning, addition of water and air-cooled walls in the furnace, the use of higher grade refractories now available, the addition of economizers or air heaters or both, improved boiler water treatment and conditioning have made it possible actually to increase the efficiency and availability in spite of the increased rating.

Steam Piping Equipment

Higher pressures and temperatures have necessitated standardization of fittings and valves up to 900 lb. 750 deg. For higher pressure and temperatures up to 1000 deg. alloy steels have been developed and used successfully and much has been learned about creep phenomena at the higher temperatures. Welded piping and fittings have been widely used, resulting in lowering of first costs about 30 per cent and maintenance costs about 80 per cent in many cases.

Development in Power Generating Units

Steam engines have undergone considerable improvement in thermal efficiency, particularly since the general acceptance of the uniflow engine. The development of the uniflow engine is the last real step in engine improvement. Water rates of non-condensing engines have decreased from around 25 and 35 lb. per i-hp. per hr. to from 15 to 28 lb. per i-hp. per hr. Rankine cycle efficiencies of modern engines run as high as 92 per cent. Increased pressures and temperatures also have contributed to higher engine economy.

Improvements in the design and application made by steam turbine manufacturers in the past ten years have made old turbines obsolete. Whereas in the period prior to 1920 only condensing or non-condensing turbines were available for industrial plant service, today we have automatic bleeder turbines, mixed pressure turbines and the non-condensing bleeder turbine. Higher steam pressures and higher temperatures, change from condensing to noncondensing operation, interconnection with public service lines, are some of the factors involved. Rankine cycle efficiencies of turbines have increased 8 per cent in the last 10 yr.

An enormous increase in the application of the Diesel engine marked the period from 1920 to 1930. Although, inherently a high economy engine, the thermal efficiency of Diesel engines has increased something like 20 per cent in the past 10 yr. New alloys and new processes in precision manufacture have helped to make the modern oil engine a better and more reliable machine. Engines have become steadily larger, the largest now being rated at 22,500 b-hp.

Although there have been many improvements in generator design, there has been little increase in efficiency, due of course, to the fact that the electric generator already had been developed to a high point of perfection. Efficiencies of modern high capacity machines run higher than 97 per cent. In respects other than efficiency, generators have undergone considerable improvement. New steels, new insulating materials, new methods of winding and bracing, improved methods of ventilating and lubricating have all combined to make the generator of today a more reliable and more compact machine than that of a decade ago.

Condensers

Measured by what is perhaps the most obvious unit, the heat coefficient, condenser performance may be said to have tripled, increasing from about 200 to 600 B.t.u. per sq. ft. per deg. per hr. Much of this improvement is due to better tube arrangement but a great deal is due to better construction, better maintenance and improved auxiliaries.

These improvements benefit plant operation by reducing the vacuum, reducing the power absorbed by auxiliaries, reducing or eliminating the hotwell temperature depression and by reducing condenser circulating water leakage. Improved heat transfer makes it possible to reduce the physical size of the shell, foundation and building. Welded shell construction promises to make further reduction in cost and weight.

Switching Equipment

The automatic oil circuit breaker has been converted from a mere device for opening a circuit to one involving a complex structure with a still more complex and fundamental theory to account for its operation. The most notable achievements in circuit breaker design, have been the development of the deion breaker and the oil blast breaker. An important feature in considering the rehabilitation of plants is the fact that deion grids can be applied to older types of oil circuit breakers, with considerable increase in the effectiveness of their performance.

Developments in transformer equipment in recent years have been directed largely toward the production of units of higher capacity per unit volume and to design which permits changing the voltage ratio under load. A marked improvement has been the development of the nonresonating transformer which supplies the capacitance charging currents of the various elements of the windings to ground by means of metallic shields. This method of construction greatly reduces the stress imposed upon the units during lightning surges.

Heating System Equipment

Heating systems have changed to air conditioning systems, Central air conditioning systems controlling both air temperature and humidity have been developed using duct distribution and recently these have been designed in unit form for installation directly in rooms to be conditioned. Direct fired fan furnace systems are now available in many forms. Unit heaters employing direct firing or indirect steam radiation have been developed in hanging and floor types, some of the latter radiating as much as 2,000,000 B.t.u. per hr. Unit coolers are a recent development using brine or cold water. Water for spray washers and air conditioners can be cooled either by brine refrigeration or directly by melting ice. Recently there has been much interest in use of refrigeration equipment for heating.

Plant Lighting Equipment

Because of the development of new lamps, new fixtures and reflectors, the recommended illumination intensities today are considerably higher than those in general use ten years ago. In many cases, this has increased 200 per cent. As a consequence, many lighting systems designed ten years ago are inadequate today. It is said by those who have investigated this question of industrial illumination, that every dollar invested to improve industrial lighting system brings an annual return of $34 from increased production and decreased accidents.

An important achievement in lamp manufacture was the development of the inside frosted bulb. Such lamps are not only more desirable from the standpoint of vision but they stay clean much longer. Lighting control equipment has been developed to a high degree of perfection and many new devices have received application, i.e., the thyratron, the Selsyn motor and the photocell. The latter has been incorporated into an automatic control unit which automatically switches on the lights when daylight falls below a predetermined intensity and extinguishes them as the natural illumination increases above this value.

Plant Power Equipment

Among the more important developments in plant power equipment are new devices for the control and regulation of load and power factor. In a plant where power is purchased, load regulators perform excellent service and reduce costs. In connection with power factor improvement, the development of the capacitor has been of great consequence. It is now possible to correct power factor at each power consuming device. In connection with control, the development of the Selsyn system has been very useful. Such systems are simple and can be used for a great variety of purposes.

Rapid deterioration of electrode holders on welding machines is usually due to the operator not getting a secure grip on the electrode before starting to weld.

Present Practice in Handling Coal

REFINEMENTS IN CONVEYORS, MORE DATA ON STORAGE PRACTICE, INCREASED USE OF WEIGHING DEVICES, DEVELOPMENT OF PULVERIZING EQUIPMENT CHARACTERIZE 10 YEARS' PROGRESS

PROGRESS in fuel preparation and handling equipment during the past 10 yr. has consisted principally in improvements in mechanical details of the various apparatus, simplification of fuel handling layouts to meet varying conditions, development of the drag scraper, reduction of friction in equipment, especially in conveyors, by the use of anti-friction bearings, and a great deal of interest in lubrication of all types of coal and ash handling equipment, especially where pressure lubrication can be employed.

There has been considerable progress also in coal storage practice. For storing coal on the ground in

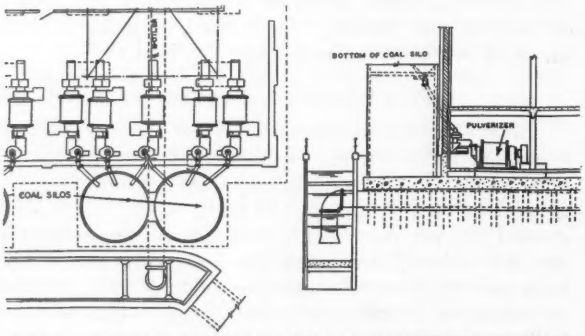


FIG. 1. AT SOUTH AMBOY, COAL IS STORED IN SILOS JUST OUTSIDE THE BOILER ROOM WALL, ELIMINATING OVERHEAD BUNKERS. FROM SILOS IT FLOWS DIRECT TO PULVERIZER FEEDERS. PLAN AT LEFT, ELEVATION AT RIGHT

storage piles, some valuable information has been accumulated, by the U. S. Bureau of Mines and other agencies, on deterioration and combustion in stored coal.

Causes of spontaneous combustion have received much study and some authorities believe that sulphur in coal is responsible for some cases of combustion. Pressure on the coal is believed to be responsible for heating of the pile, and because of this, it is advocated that piles should not be higher than 15 to 20 ft. In some cases, it is found, however, that coal can be piled 25 to 30 ft. high without trouble. Various types of portable pyrometers for measuring the coal in piles have been developed, as well as types of pyrometers that can be inserted in receptacles placed in the coal pile when it is formed. If the temperature in a coal pile goes as high as 140 deg., it should serve as a warning. If it increases to 150 or 160, the coal should be moved and spread out to cool; while at 180 deg. bituminous coal will begin to smoke and spontaneous combustion is imminent.

General practice nowadays is based on excluding as much air as possible from the pile. Many companies are packing the coal either by rolling it in layers 1½ or 2 ft. thick or by using a tamping weight. Coal can be placed in layers by wheelbarrows or by dropping it gently from the crane bucket. Storage of coal under water is frequently practiced to reduce deterioration.

In recent years there has been considerable development of the silo for storage of coal, usually combined with a bucket elevator to fill the silo or to take coal from the bottom of the silo and discharge it above to conveyors. In small plants and often in office buildings and institutional plants, where coal is received by truck, steel bunkers in the upper part of the boiler house are used for storage. An original method of using silos is shown in Fig. 1.

Wide variety of equipment is used to store coal in open piles. Locomotive cranes, bridge cranes, cable cranes are among the equipment used. In recent years many types of plants have installed drag scrapers for storing and retaining coal. The accompanying table shows typical costs of some types of coal-storing equipment. A typical dragscraper installation covering a storage area of 50 by 350 ft. in which a maximum of 15,000 t. could be stored shows a cost of equipment of 92 cents per ton, and total operating cost, including insurance and investment charges of 25.6 cents per ton. In this particular case, however, the actual coal moved in and out of storage was 50,000 t. so that if only the 15,000 t. of coal had been handled, the items of power, labor, maintenance and depreciation would have been less than the figures given.

Methods of unloading coal from barges include mast and gaff cranes, coal unloading towers, traveling bridge cranes and the like. For unloading coal from cars, revolving car dumpers are available and there are several types of portable conveyors for unloading hopper bottom cars directly to storage piles. A common method of unloading coal from hopper bottom cars is to dump it into a track hopper from which it can either be distributed to the storage pile or taken by conveyors to the boiler house storage bunkers. Pneumatic systems for handling coal have been used, operated either by a vacuum created by an air exhauster or by a steam jet which draws the coal into the inlet head.

CONVEYING EQUIPMENT

For conveying coal to the boiler house, belt conveyors are often used, as well as bucket elevators and skip hoists. As the bucket elevator is not convenient for horizontal runs, pivoted bucket elevators and the gravity discharge conveyors are designed for both elevating and conveying horizontally. For horizontal run, the drag conveyor, consisting simply of a heavy flat chain drawn along the bottom of the trough or the plate conveyor, made by fastening steel plates or vertical plates to the chain, has often been used. Small coal is often distributed in bunkers by screw conveyors and they are sometimes used as transfer conveyors between the different parts of the system, especially in pulverized coal preparation plants. Screw conveyors for coal range in diameter from about 9 in. handling about 15 t. an hr. to 16 in. diameter handling about 75 t. an hr.

The belt conveyor has been developed to convey large

quantities of coal over long distances, either for straight horizontal runs or can be arranged on inclines up to 18 deg. It is sometimes used to convey coal from storage or unloading hoppers to the bunkers, where it transfers the coal to another belt conveyor equipped with a tripper running over the bunkers.

While the use of anti-friction bearings on belt conveyors increases the cost of the conveyor as a whole, power consumption is greatly reduced, usually to about 60 per cent of that required with plain bearings.

TABLE SHOWING COSTS OF HANDLING COAL IN STORAGE

Plant No.	Storage capacity	Method of handling	Inv. per ton	Operating Expense in and out per ton
		Public Utility Plants		
1	250,000	Gantry and loco. cranes...	$5.82	$0.57
2	99,500	Traveling bridge	5.83	0.25
3	65,000	Loco. crane, belt conveyor	2.30	0.16
4	30,000	Tower and loco. crane....	6.88	0.12
5	25,000	Loco. crane	2.00	0.50
		Industrial Plants		
1	95,000	Gantry crane	$1.13	$0.06
2	20,000	Trestle, loco. crane, scraper	.75	0.40
3	12,000	Loco. crane	1.25	0.15
4	12,000	Loco. crane	2.00	0.16
5	10,000	Gantry crane	4.00	0.10
6	10,000	Steam shovel	.80	0.85
7	10,000	Elevator, dump cars.....	2.50	0.25
8	7,000	Track hopper, elevating and dist. belts.....	2.85	0.45
9	6,000	Loco. crane	2.83	0.06
10	5,000	Monorail and clamshell...	4.00	0.04

Weighing Coal for Performance Records

In discharging coal from the boiler house bunkers to the coal burning equipment, many plants have installed various types of weighing devices. In some cases, automatic coal scales, making a continuous record of coal weight, have been employed and in other cases, weigh larries running along underneath the bunker and drawing coal from various parts of it, have been used to serve an entire battery of stokers or pulverizers. Some plants weigh coal in the cars before putting it into outside storage and in several important plants using belt conveyors, automatic scales have been placed between the outside conveyors and the conveyors running over the bunkers. Various types of coal meters and coal samplers have been developed for installation on belts leading from bunkers or pulverizers or in spouts. Another type of meter is attached directly to the stoker crank shaft to count its revolutions, while still another is actuated by oil pressure. With chain grate stokers, coal is sometimes measured by calibrating the height of the stoker gate in combination with the speed of the grate surface. For measuring pulverized coal, coal bins are mounted on scales with flexible pipe connection and the speeds of coal feeders discharging to coal burners, are also used to give the measurement of quantity. On such types of pulverized feeders, coal is pushed by a rotary element through apertures into place and these can be calibrated to give a measurement of the coal used.

One of the outstanding recent developments in coal weighing equipment, as used in two modern central stations, consists of a short belt conveyor mounted on scales. This belt conveyor feeds coal directly to the pulverizing mill and the scale indications can be transmitted by Selsyn motors to the boiler operating board.*

Considerable work has been done in the development of nonsegregating coal hoppers and coal spouts designed to prevent stratification of the coal in stoker hoppers.

Pulverized coal and green coal for the pulverizing system is transported by screw conveyors, air pressure systems, air mixing systems and pumping systems using screw or rotary pumps.

For handling ash a simple method, although not necessarily the best, is to drop it through ash gates at the bottom of the furnace into railroad cars or industrial cars. Sometimes the same bucket conveyor that handles coal is also used for handling ash. Chain conveyors and belt conveyors have been used for this service, but it is often found that the ash has a high abrasive action on these. There has been frequent use of a separate skip hoist to convey the ash to a storage bunker, from which it can be removed by trucks or railroad cars. Many installations of steam jet ash conveyors have been made and there has been widespread use of sluicing systems, in which jets of water at high pressure are used to discharge the ash to overhead tanks or to carry it outside the plant for filling in low areas around the plant.

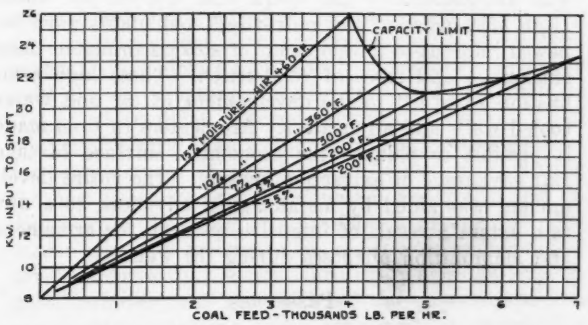


FIG. 2. PERFORMANCE OF A PULVERIZER WITH VARYING AIR TEMPERATURES AND MOISTURE IN COAL

Development of Pulverizing Equipment

In the field of pulverizing equipment, so far as this is used in power plant work, the major developments have all occurred within the past 10 yr. Various types of impact, roller and ball mills have been developed in increasing sizes, until now it is possible to obtain a single pulverizing mill with a capacity of 50 t. an hr. The costs of pulverizing have constantly decreased until at the present time we find stations employing unit pulverizing systems with total preparation costs ranging between 11.02 and 18.89 cents per t. For central or bin systems, costs between 16.26 and 25 cents per t. are given, including power, labor, lubricant, material and all maintenance charges. The separate coal drier which was used for drying the coal before sending it to the pulverizing mill, in the earlier days of development, seems to be giving way to the use of mill drying, which has been used successfully by a number of stations.

Safety devices such as holdbacks and interlocking control switches have been developed for conveyors and there have been many refinements in skip hoist design such as automatic control, limit switches and slack cable safety switches.

*See South Amboy—It's Different, Power Plant Engineering, page 788, July 15, 1930, and Bremo—An Outstanding Central Station, page 486, May 1, 1931.

The Upward Trend of the Boiler Room

SIXFOLD INCREASE IN AVAILABLE BOILER PRESSURE; INCREASE OF 300 DEG. IN TOTAL STEAM TEMPERATURE; THREEFOLD INCREASE IN BOILER RATINGS; SINGLE BOILERS MAKING OVER A MILLION POUNDS OF STEAM PER HOUR AND 10 TO 15 PER CENT INCREASE IN EFFICIENCY RESULT OF DEVELOPMENTS DURING PAST DECADE

EVOLUTION of steam generating practice during the past decade is known in a general way but even those intimately connected with the industry often fail to appreciate fully the speed with which this evolution took place. Advantages of high pressures, high temperatures and high boiler capacities were appreciated and even tried experimentally, during the nineteenth century but the limitations imposed by available metals, cheap fuel and comparatively small power loads delayed commercial realization of these advantages until the last few years.

It is impossible to point to any one factor responsible for this almost unbelievable progress. High fuel prices and greatly increased power loads from motorized industries furnished the incentive and pulverized coal was unquestionably the spark that started the blaze. High efficiencies of the pulverized coal plants gave renewed impetus to development of stokers to match these efficiencies and rates of combustion. These high combustion rates led to the development of air and water cooled walls and air heaters. Air heaters in turn made it possible to balance the economizer surface to take full advantage of extraction heating. The entire development was aided by metallurgical advances, to a certain extent a result of intensive research for armament and ammunition purposes during the war.

PRESSURES

Steam pressures which had been gradually increasing from a few pounds gage, as used in the time of Watt, to about 400 lb. were, in 1924, suddenly increased to 600 and 650 lb., followed a couple of years later by 1000, 1200 and 1400-lb. and last year by 1800-lb. plants Progress since 1900 is outlined roughly by Fig. 1. Because of the fact that the plants are grouped in distinct and separate pressure ranges, it is impossible to draw a curve which would represent a gradual increase of pressure with time although this is indicated roughly by the dotted line. At present, boilers up to 1800 lb., in this country and to 3200 lb. in Europe, are in operation and any pressure up to these limits may be considered as commercially available.

In the central station group, plants are now divided into three distinct classes: First, single expansion plants up to about 450 lb. pressure; second, reheat plants in the 600-650 lb. range; third, reheat plants in the 1200-1400 lb. range. These divisions are more or less fixed by the temperature limit of 750 deg. F. considered as maximum up to this time. Increase of the temperature limit to 850 will raise the single expansion pressure limit to 600 or 650 lb., so the 600-800 lb. reheat band may be considered as a temporary development bridging the 450-1200 lb. gap. Heretofore, forged drums necessary for high pressure added materially to boiler costs; changes in the boiler code to allow welding together with improved welding technique may, however, be expected to cause a substantial reduction in high pressure boiler costs.

In the industrial field, such pressure and temperature relations (determined by the allowable moisture in the turbine exhaust) are not found and initial pressure selection is largely a matter of process requirements and the relation of the electric and process steam loads. Process demands alone may dictate a boiler pressure of 1000 lb. as it has in one plant or the combined demands of power and steam may set the pressure at any intermediate pressure[1] up to 1800 lb. (or even 3200 lb.) without reference to well defined groups as in the central station. With high electric to steam ratios, high pressures are necessary and reheat will probably be advisable in order to keep within the maximum temperature limit set by available materials. Probably the best examples of industrial plant load balanc-

[1]See Power Plant Engineering, p. 1141, Dec. 1, 1931.

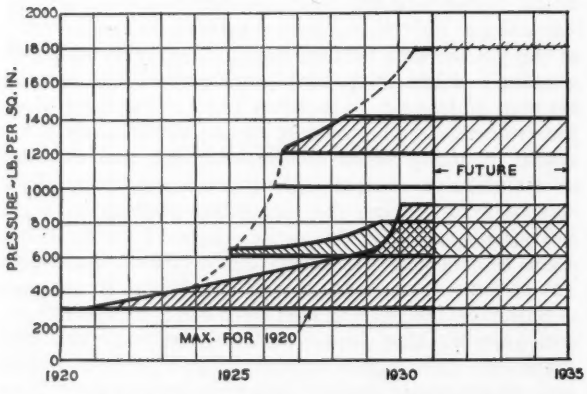


FIG. 1. COMMERCIAL STEAM PRESSURES HAVE INCREASED SIXFOLD DURING THE LAST DECADE. CROSS HATCHED AREA INDICATES APPROXIMATE INCREASE IN MAXIMUM AVAILABLE SINCE 1920

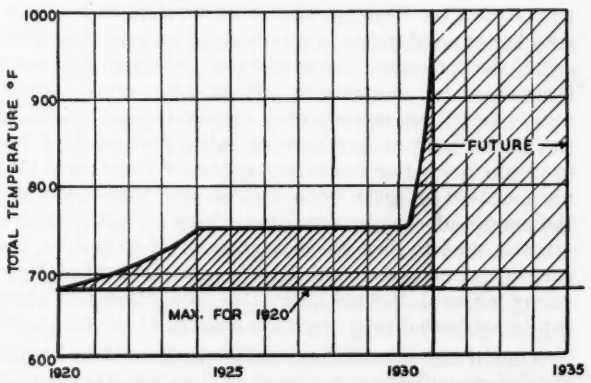


FIG. 2. MOST SIGNIFICANT OF RECENT DEVELOPMENTS IS THE INCREASE IN TOTAL TEMPERATURE TO 850 AND 1000 DEG. F. CROSS HATCHED AREA INDICATES INCREASE SINCE 1920

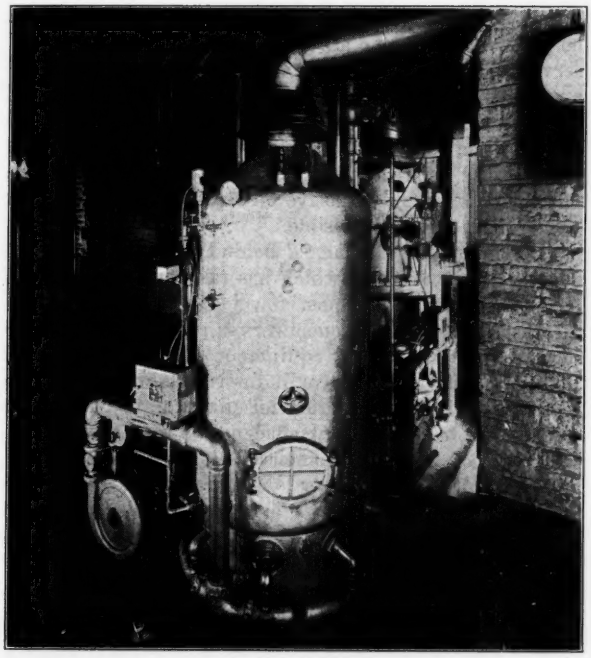


FIG. 3. SMALL AUTOMATIC GAS FIRED BOILER BUILT IN SIZES DOWN TO A FEW BOILER HORSEPOWER

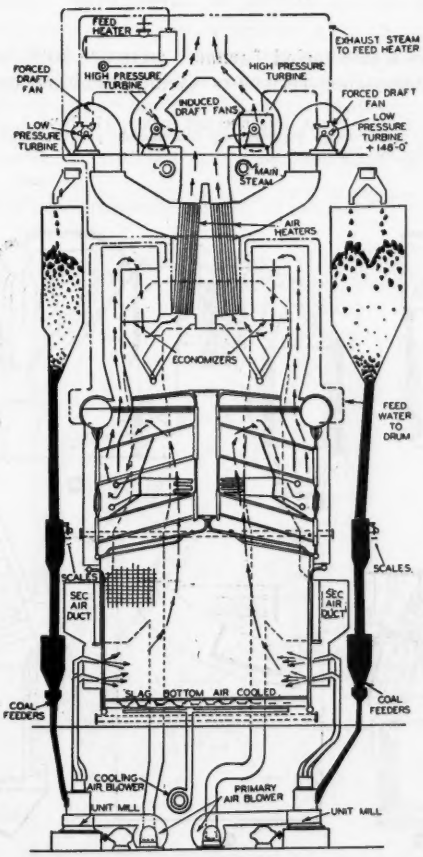


FIG. 4. NEW DOUBLE BOILER WHICH HAS MADE OVER A MILLION AND A QUARTER POUNDS OF STEAM PER HOUR.

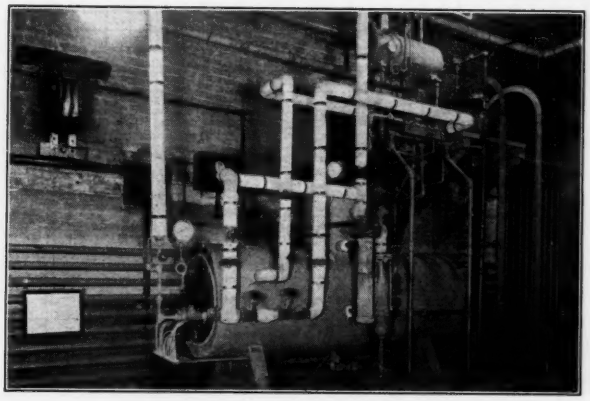


FIG. 5. ELECTRIC STEAM GENERATORS HAVE FOUND A CONSIDERABLE FIELD IN INDUSTRY

ing are represented by two 650-lb. plants completed about a year and a half ago and two industrial reheat stations completed this year.[2]

Temperatures

Before the introduction of the turbine, saturated steam or steam with a few degrees of superheat was in general use. High superheat increases turbine efficiency to a marked extent, however, and by 1920 steam temperatures had slowly increased to about 675 deg. F. In 1924 the early reheat stations[3] increased this limit to 750 at which point it remained until this year. Completion of several plants (industrial and central station) for temperatures of 800, 850 and 1000 deg. F. during the past year, changes the situation materially and indicates that these temperatures are available for companies who are willing to do a little experimental or development work. As standard equipment 750 deg. F. must, however, still be considered the upper limit. Demand of a prominent boiler company for superheater metals capable of withstanding a metal temperature of 1300 deg. F. indicates the progress expected in future high temperature work.

Capacities

Large units offer advantages in first cost, space requirements and operating expense so that high capacities have been developed to meet ultimate demands in this connection, i.e., a single boiler for each turbine. These large capacities have been obtained in two ways: first, by practically doubling or even tripling the rating of the boiler; second, by increasing its physical size.

At the peak of this development is the big double boiler[4], shown by Fig. 4, with a nominal rating of about 6500 hp. and which has already made over a million and a quarter pounds of steam per hour, even this limitation being set by factors outside of the boiler and furnace, namely the size of the feedwater piping. Another station under construction will have an 80,000-kw. turbine and a single 1400-lb. boiler. Nor has this development been altogether in the central station field, an outstanding industrial unit being a 900-lb., 29,812-

[2]See Power Plant Engineering descriptions of Waldorf plant, page 734, July 1, 1930; Champion Coated Paper plant, page 1328, Dec. 1, 1930; Ford plant, page 354, Mar. 15, 1931, and Ilse plant, page 1058, Nov. 1, 1931.

[3]See Power Plant Engineering, page 842, Aug. 15, 1931, for list of reheat stations.

[4]See Power Plant Engineering, page 799, Aug. 1, 1931, for further data on Hell Gate.

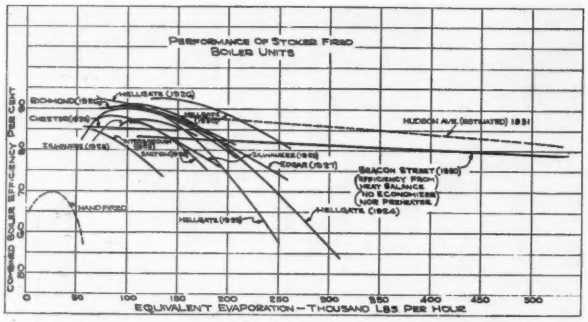


FIG. 6. CURVES SHOWING THE STEADY INCREASE IN EFFICIENCY AND CAPACITY AS REPRESENTED BY STOKER FIRED BOILER TESTS

sq. ft. boiler with a capacity of almost 350,000 lb. of steam per hour (400 per cent rating) installed in a paper mill.[2]

From these unusually large sizes down to the very smallest there is an unbroken range of sizes to meet any conditions that might arise. Development of the smaller boilers has been rapid and fully as startling as the larger sizes. Figure 3 shows a small 125-lb. gas fired boiler with complete automatic control for industrial service. Boilers of this type, the largest of the automatic gas fired boilers, are built in sizes from 125 b-hp. down to a few horsepower and for pressures up to 200 lb. Electric boilers have also found a considerable place in industry of recent years, Fig. 5 showing a small one installed in an explosive atmosphere where a spark or flame was not permissible.

Efficiency has not lagged behind. Curves of Fig. 6 show the improvement which has taken place in overall efficiencies during the past few years. When it is remembered that with economizers, air heaters, good furnace design and firing equipment these present high efficiencies are available for industrial as well as central stations, the average industrial plant of a decade ago with its 50 to 60 per cent efficiency is seen to be hopelessly out of date. Efficiencies have been increasing at the rate of approximately one per cent a year until they are now near the ultimate achievable so that a plant can be put in today secure in the knowledge that in four or five years its efficiency will not be hopelessly behind the standard of design then available.

Steam Generating Units Show Great Change

SUPERHEATERS, REHEATERS, AIR-COOLED WALLS, WATER WALLS, NEW FURNACES AND FUEL FIRING EQUIPMENT NOW OVERSHADOW THE ACTUAL BOILER IN IMPORTANCE

TAKEN BY ITSELF, boiler design has changed little during the past ten years, American practice tending to adapt the well proven straight and bent tube designs to the higher pressures, in contrast to European practice, which seems to tend toward entirely new designs such as the Benson and Loeffler types. A notable exception is the 1800-lb. design shown by Fig. 1E, which departs from past bent tube designs. A 3500-lb. experimental boiler is now being tested at Purdue University. This is known as a once-through series boiler, the furnace wall being made up of spiral wound tubes which act as steam making and superheating surface. An economizer is mounted above the furnace.

But today the boiler itself is only a part of the steam generating or steam making unit. Air-cooled walls, water walls, economizers, air heaters, furnace design, adequate feedwater treatment and firing equipment are the factors that determine the capacity and efficiency of the unit. With the higher rates of firing and high heat releases in the furnace, maintenance on the old type solid refractory walls was high and the air-cooled wall was developed. In this type of wall, some of the air for combustion is drawn through ducts in the furnace walls. This cooling reduces maintenance and radiation losses and at the same time heats the air on the way to the furnace and so improves combustion conditions.

Further advances in firing equipment called for even more cooling than afforded by the air ducts, so water-cooled walls of various types were developed. Some of these use bare tubes close together, some use bare tubes spaced on 6 to 18-in. centers, some use tubes with face coverings of metal or refractory, some use an almost complete water-cooled furnace, some use both air-cooled and water-cooled sections in various combinations.[1]

[1]See Power Plant Engineering, page 617, June 1, 1930, The Field for Air-Cooled Refractory Furnaces; p. 890, Sept. 1, 1930, Water Cooled Furnaces.

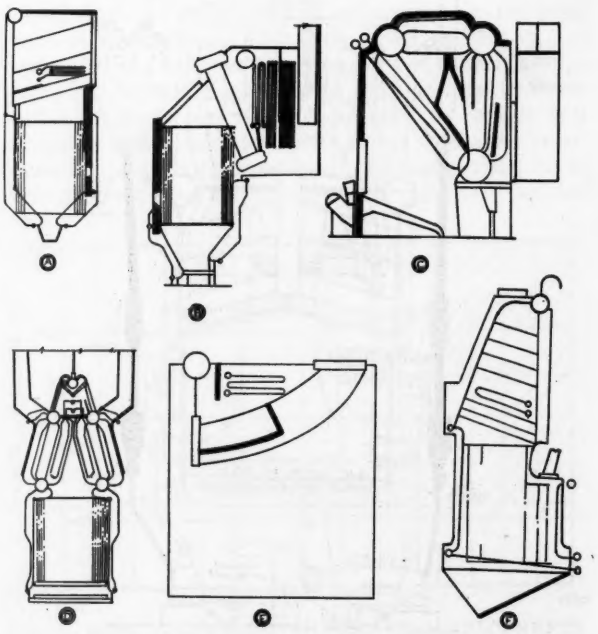


FIG. 1. TUBE ARRANGEMENTS OF SEVERAL RECENT INDUSTRIAL PLANTS RANGING FROM 400 TO 1800 LB. PRESSURE

Furnace Walls

In some of the new boilers, the water cooling surfaces may make 50 per cent of the total amount of the steam generated by the unit. One of the most striking effects of water wall surfaces for boiler plant rehabilitation purposes is shown by Fig. 2. This is an industrial plant installation[2] where the capacity of three 312-hp. boilers was increased about 60 per cent at a cost of about $50 per boiler horsepower of peak capacity. The important point, however, is that the efficiency was increased so that approximately 14,000 t. of coal was saved annually. It must also be remembered that the plant replaced was not an old one but a recent one, considered advanced design in 1924. The cost of the entire job was about $25,000 for each unit, about half of which was the cost of the stokers and water walls.

Slag Screens

An important point to notice in Fig. 2 is the construction of the water walls to form a slag screen. With high rates of firing, the slag screen is important as bits of molten ash are carried along and tend to stick to the tubes. With tubes closely spaced as in a boiler, this ash soon bridges over and stops up the gas passages. Slag screens are widely spaced tubes, easily reached with a hand lance, which do not readily bridge over. Their function is to cool the gases below the fusing point of the slag so that it will solidify before it reaches the boiler tubes. Sometimes alternate tubes of the bottom rows of boiler tubes are left out as in Fig. 4, to give the same effect.

Superheaters have also undergone a big improvement because of the steadily increasing demand for higher superheat. Convection superheaters have in many cases been moved nearer the fire. Formerly they were always placed between the first and second passes while now it is common to split the first pass tube bank to include

[2]See Power Plant Engineering, p. 1273, November 15, 1930, Revamping Boiler Increases Capacity 60 per cent.

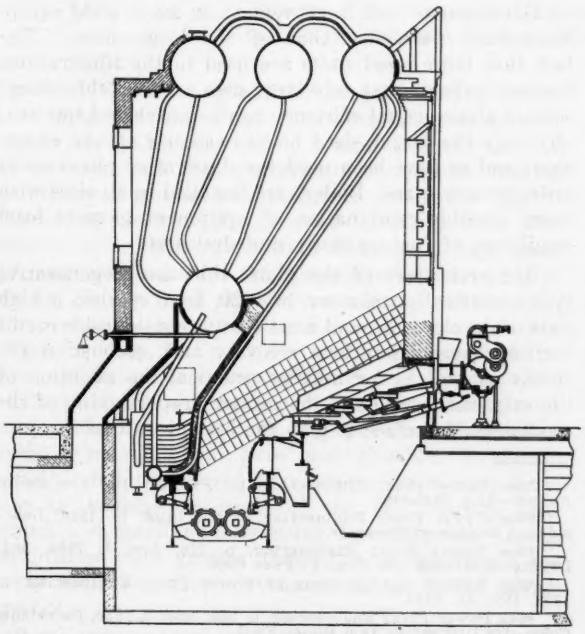


FIG. 2. WATER WALLS ADDED TO THIS BOILER INCREASED ITS CAPACITY 60 PER CENT

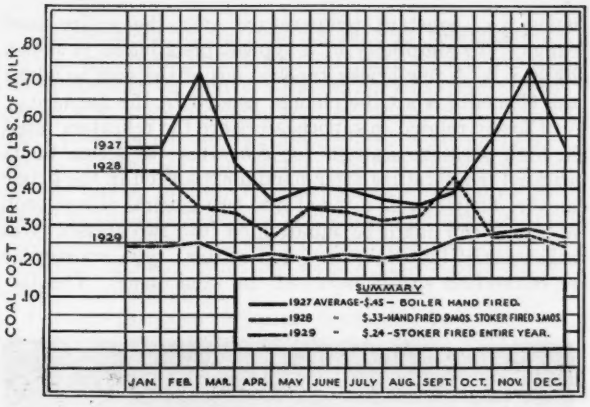


FIG. 3. STOKERS ADDED TO THIS 168-HP. H.R.T. BOILER CUT THE COAL COST ALMOST IN HALF

the superheater as shown by Fig. 1A. These sketches also show the change in baffling arrangement. Formerly only about half the lower rows of tubes were included in the first pass. It is now common practice to include all the lower rows of tubes in the first pass where the more rapid heat transfer of radiant heat greatly increases the steaming capacity.

Radiant superheaters[3] are another new development particularly adapted to the industrial plant for purposes of increasing the total temperature of the steam. They may be used alone or in series with convection heaters to boost the superheat and also to give better character-

[3]See Power Plant Engineering, p. 427, April 15, 1930, Radiant Superheater Finds Wide Application.

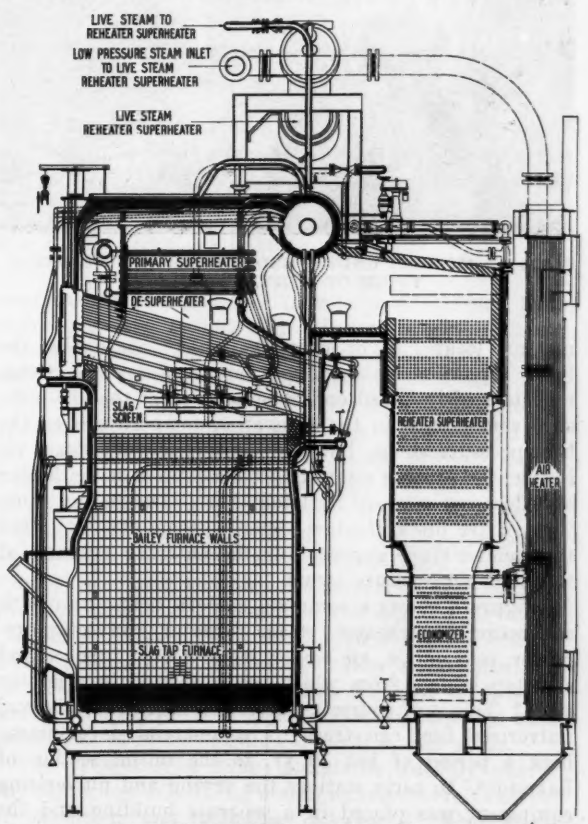


FIG. 4. A COMPLETE MODERN BOILER UNIT WITH WATER WALLS SUPERHEATER, STEAM AND GAS REHEATERS, ECONOMIZER AND AIR HEATER

istics, i.e., constant temperature over the entire load range. The simplicity of a typical installation is shown by Fig. 5. A few bricks knocked out of the wall to admit the elements is all the change needed in the furnace.

Closely related to superheaters are the reheaters[4] used in high pressure stations for reheating the steam to its original temperature after partial expansion in the prime mover. They can be divided into two general classes each of which can again be sub-divided into two classes. Gas reheaters of the convection and radiant type are similar to convection superheaters of the same name. The former are located in, or after, the boiler tube banks; the latter replace a section of the water-cooled walls. Steam reheaters of the dead end type can reheat the low-pressure steam only to the saturation temperature of the high-pressure steam, but in the thoroughfare steam reheater, the heating steam is not condensed in the heater and does not give up its latent heat. Depending upon the relative flows, the low-pressure steam can be heated to a temperature approaching the entering pressure of the high temperature steam.

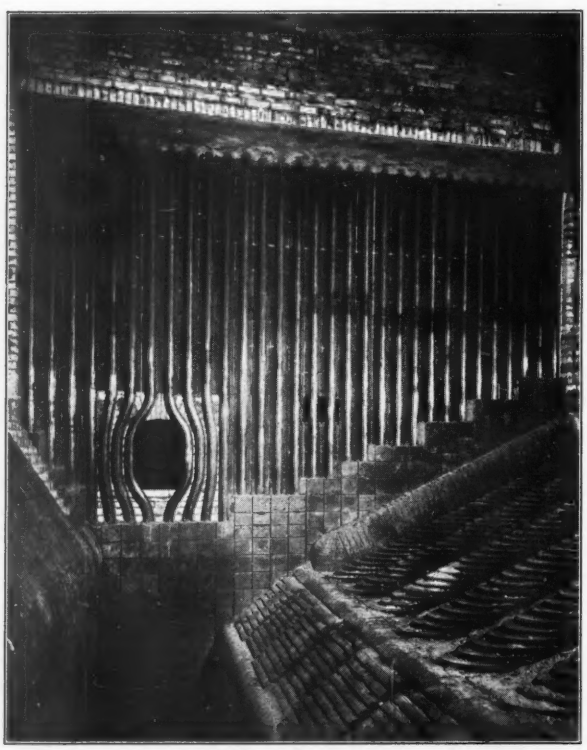


FIG. 5. A MODERN UNDERFEED STOKER WITH SEVERAL TYPES OF FURNACE WALL

Figure 4 shows a complete modern boiler unit with convection superheater, steam reheater, convection reheater, economizer, air heater, water-cooled furnace and slag tap bottom from which ash is tapped in a molten state.[5] This is of course a pulverized fuel fired unit and pulverized fuel can trace its commercial development back a period of but 10 yr. to the initial section of Lakeside[6]. In early stations the drying and pulverizing equipment was placed in a separate building and the pulverized coal stored in a bin preparatory to firing. This was known as the central or bin system. Later the unit system, in which the pulverizing mill or mills discharge directly into the furnace, was developed. Both systems are widely used at present, although in the later stations the preparation house for the bin system has been abandoned and the mills are now located in front of the boilers as in the unit system but with a small storage bin in between the mill and burners.

Coal dryers, as such, have been practically eliminated within the past three or four years and the coal is now dried in the mill by means of heated air or flue gas.[7] Another recent change tending to reduce maintenance charges is the placing of the exhauster fan at the entrance to the mill so that it handles only clean air and is not subjected to erosion from the coal dust. Turbulent burners have largely replaced the older straight shot type and heat releases per unit of furnace volume in the newer plants range from 20,000 to 30,000 B.t.u. per cubic foot.[8]

Practically all fuel burning methods have been improved equally as much. Petroleum coke[9], natural gas, oil[10] and particularly underfeed stokers have passed through almost unbelievable improvements. Underfeed stokers with a projected grate area of 750 sq. ft. have been built. Normal steaming capacities of a single stoker fired boiler have reached well over half a million pounds per hour while units for over a million pounds per hour have been proposed. Stoker widths of 35 ft. have been made in Europe but the largest single units in this country are the Hudson Avenue stokers, somewhat over 26 ft. wide and nearly 27 ft. long. In 1920 there were a number of double fired installations with a length of 19 ft. A double unit using the long stoker of today would have a length of over 50 ft. In 1920 one type of chain grate stokers were designed to burn 40 to 45 lb. of coal per square foot while today, with forced draft and preheated air, a heavy duty stoker of the same type will burn around 65 lb. per. sq. ft.

Development and improvement on small sized equipment have paralleled that of the large sizes. The fact that large sized units are used in the illustrations does not indicate that only large sizes are available. Small sizes of almost equal efficiency can be purchased but usually only the larger sized boilers can use all the equipment and so have been used for illustrative purposes in order to save space. Boilers are installed in all sizes with every possible combination of equipment to meet local conditions of fuel, capacity and first cost.

Air preheaters of the plate, tube and regenerative type, practically unknown in 1920, have reached a high state of development and must receive considerable credit for improvements in heat recovery and combustion efficiency as well as for making practical the adoption of the extraction cycle and the proper proportioning of the economizer[16] surface to give the best overall economy.

[4]See Power Plant Engineering, p. 697, July 1, 1931; p. 840, Aug. 15, 1931. Reheat — Practice, Operation and Control.

[5]See Power Plant Engineering, p. 788, July 15, 1930, South Amboy—It's Different.

[6]See Power Plant Engineering, p. 830, Aug. 15, 1930, Lakeside—A Decade of Progress.

[7]See Power Plant Engineering, p. 376, Apr. 1, 1930, Mill Drying Coal with 550 Deg. F. Flue Gas.

[8]See Annual Review issue of Power Plant Engineering, p. 1397, Dec. 15, 1930.

[9]See Power Plant Engineering, p. 268, Mar. 1, 1930, Petroleum Coke—Its Utilization as a Boiler Fuel.

[10]See Power Plant Engineering, p. 664, June 15, 1930, Station A.

Use of pulverized fuel has brought about a problem which was particularly troublesome to stations near thickly populated districts, that is the discharge of cinders and fly ash from the stack. Electrostatic precipitators, bag filters, spray washers and traps of various kinds have been developed. Still another problem which is becoming of unusual importance and which has been but partially solved is the elimination of noxious gases, namely sulphur dioxide and carbon dioxide, from the stack discharge. Corrosion in the high sulphur coal districts has exacted a heavy toll in the past but the problem is being approached by careful research[11] with prospects that sulphuric acid and solid carbon dioxide may soon be byproducts of the power industry.

Automatic combustion control had been successfully applied to fuel oil stations by 1920 but its application to coal firing was usually limited to operation of the dampers and stoker speed. Today even standby stations can be arranged to come into service automatically[12] or a change over from say gas to pulverized fuel can be made without the need for human intervention.[13] Stoker fired plants have equally successful applications and it is safe to say that combustion control can be devised to make the station operation entirely automatic if necessary.

[11]See Power Plant Engineering, p. 973, Aug. 15, 1931, Removal of Sulphur Dioxide from Flue Gases.

[12]See Power Plant Engineering, p. 1155, Oct. 15, 1930, Automatic Control for Standby Plants.

[13]See Power Plant Engineering, p. 874, Sept. 1, 1931, Youngstown Sheet & Tube Co. power plant.

[14]See Power Plant Engineering, p. 190, Feb. 1, 1931, Embrittlement and Protection of Steam Boilers.

[15]See Power Plant Engineering, p. 751, July 15, 1931, Evaporator Practice and Design.

[16]See Power Plant Engineering, p. 1214, Nov. 1, 1930, How Do You Select Your Economizer?

Improvement in instruments such as thermometers, pyrometers, gages and flowmeters, with remote reading and application to control of operations has had a great influence in station design and operation. Some of the newer plants are under complete control and supervision from a central point or station. Safety valves, valves, blowoff valves, piping, water columns, breechings and similar equipment have undergone an equal development while auxiliaries such as fans, feed pumps and feedwater regulators are now available with a high degree of reliability and efficiency.

Perhaps the most important operating improvement, however, has been the progress made in solving the feedwater problems brought about by high pressure. Embrittlement studies[14] backed by operating experience have produced definite methods of control of this dangerous cracking which in the past took such heavy toll in damage and held such potential danger to operators. Boiler and feedwater conditioning has reached the stage where practically any water can be brought up to the standard set by modern high-pressure, high capacity stations. Corrosion is successfully treated by using protective coatings of the internal surfaces; by thermal and chemical deaerators; by chemical treatment; or by a combination of the above. Continuous blowdown systems have done much to enable the operator to maintain a satisfactory concentration without excessive heat losses.

In this connection evaporators for providing pure boiler feed makeup have played a great part. Sometimes their use eliminates or minimizes to a certain extent the expense of chemical treatment but usually the feed to the evaporator is treated,[15] either for the purpose of increasing the evaporator capacity without carryover or making the scale easier to crack from the heating coils.

Ten Years of Progress in Piping Design

HIGHER PRESSURES AND TEMPERATURES LEAD TO NEW MATERIALS AND IMPROVED DESIGN. WELDED PIPING DEVELOPS RAPIDLY

PROBABLY no single factor in power plant design during the past 10 yr. has been of more general interest than the question of piping and fittings for high-pressure and high-temperature equipment. One of the principal reasons why designers have been able to take advantage of the economies in design and construction afforded by generation of steam at high pressure and temperature is that the manufacturers of piping and fittings and the various research workers on these materials have developed new metals and new designs to keep pace with the evolving designs of the boiler and prime mover manufacturers. In short, without the methods and equipment to control steam and water at high temperatures and pressures the entire development would not have been possible. It should be noted that the use of high temperatures and pressures in various processes of the oil industry also created a demand and necessity for improved piping and fittings even greater than that of the power industry and that these developments all moved along together.

Some years ago, up to the period just before the World War, the maximum steam pressure in a power plant seldom exceeded 200 lb. with a total steam temperature of 480 to 500 deg. Under these conditions, low carbon steel pipe with cast iron valves and fittings were fairly satisfactory. Soft gaskets were used and ordinary bolts held the joints together. Questions of expansion, creep, embrittlement, crystallization and the like were practically unknown.[1] Steam pressure began to increase, however, just before the war and in 1917 the Joliet power station was built for a steam pressure of 300 lb. and a temperature of 600 deg. F. The trend toward high pressures and temperatures continued after the war and we now have several central stations operating at 1200 lb. to 1400 lb. 750 deg. F., an industrial plant designed for 1800 lb. 850 deg. F., a central station designed for future operation at 850 deg. F., a moderate pressure unit that has operated for a short time at 1000 deg. F. and experimental boilers that have operated at pressures as high as 5000 lb. per sq. in.

The present steel flange standards used by practically all piping and fitting manufacturers were designed for use up to and including 750 deg. F. when made

[1]See Metallurgical Requirements for High Temperature Steam Piping by F. W. Martin presented in symposium before joint A.S.M.E. and A.S.T.M. meeting, June, 1931.

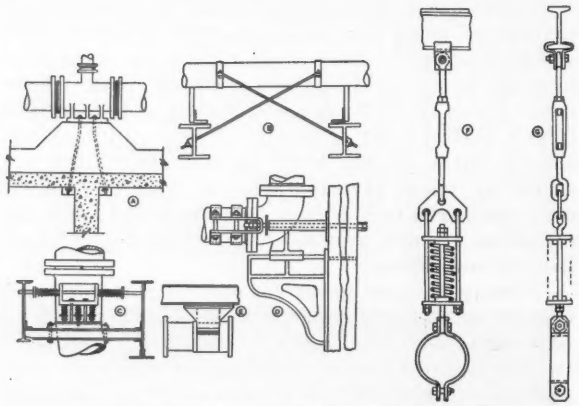


FIG. 1. SEVERAL TYPES OF PIPE ANCHORS

up in carbon cast steel with a minimum yield point of 36,000 lb. per sq. in. At the present time, most piping designers have limited themselves to seamless steel tubing for all pressures above 400 lb. per sq. in and for temperatures up to and including 750 deg., a design based on a modified formula as given in the A.S.M.E. boiler code. For resisting the pressure, the pipe must be made heavier and while it might seem that this would increase the cost, it should be remembered that as the steam pressure increases, its relative volume decreases. The high temperatures involved introduce the phenomenon of growth or creep and a great deal of investigation has been conducted on this subject. It only applies to pipe insofar as it may cause a reduction in the thickness of the pipe wall to the point of failure. Since power plants are often designed for useful life of at least 20 yr., the allowable increase in size of pipe is such that during the life of the equipment it will not reach the bursting point.

Fittings are usually made of cast steel for service where the temperature is not over 750 deg. and forged steel fittings have also been used extensively for such service. For service at 850 deg., at least one manufacturer is using a chromium nickel alloy cast steel, the characteristic curves of which indicate that the material is stronger at 850 deg. F. than carbon steel castings at 750 deg. and just as strong at 1000 deg. F. as carbon steel at 750 deg. F. For the 1000-deg. installation referred to above, the pipe is of chrome nickel steel alloy and this is used for some of the castings as well.[2] Valves for high temperature service are usually made of a body, bonnet and disc of cast material with fittings of various alloys, such as nitr-alloy, stainless steel, chrome nickel steel and the like. Bolts are usually of alloy steel with nuts mostly of plain carbon steel either cold punched or cold pressed. Motor-operated valves, sometimes controlled from remote points, have been valuable in operation, as large high-pressure valves require much force to operate. They also provide a safety feature through remote control.

Most joints for temperatures of around 750 deg. are of the metal to metal type, or if gaskets are used, they are either monel metal or soft steel. All of the foregoing applies to high pressures and temperatures which require special consideration. For industrial plants operating at pressures of 400 to 600 lb. and temperatures up to 700 or 750 deg. which are considered somewhat high in an industrial plant, the standard lines of 400, 600 and 900-lb. American Standard valves and fittings are readily procurable from a large number of metal manufacturers, while for lower pressures, iron and steel pipe and fittings and many types of valves are available which have been proved satisfactory and dependable in hundreds of plants.

[2]Steam Piping for 1000 Deg., page 606, Power Plant Engineering, June 1, 1931.

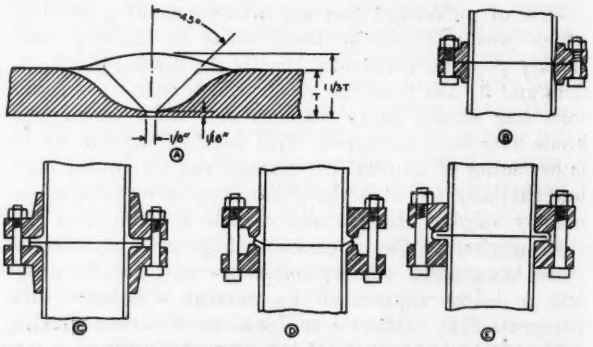


FIG. 2. TYPICAL BUTT WELD AT A. DIFFERENT TYPES OF FLANGED JOINTS SHOWN AT B, C, D AND E

Changes in steam and water pressure conditions in the power plant have also affected somewhat the question of steam and water velocity permitted in piping. Steam velocities may range from 4000 to 6000 ft. per min. for low pressure saturated steam lines, 6000 to 8000 ft. per min. for moderate pressure saturated steam lines, such as for reciprocating engines and general heating lines, 10,000 to 15,000 ft. per min. for moderate and high pressure superheated steam turbine leads and as high as 50,000 to 75,000 ft. per min. for district steam heating feeder lines. These velocities will depend upon local conditions, steam quality, steam pressure and the pressure drop that can be allowed. For building heating systems, velocities must be kept low because of noise, while with reciprocating engines and

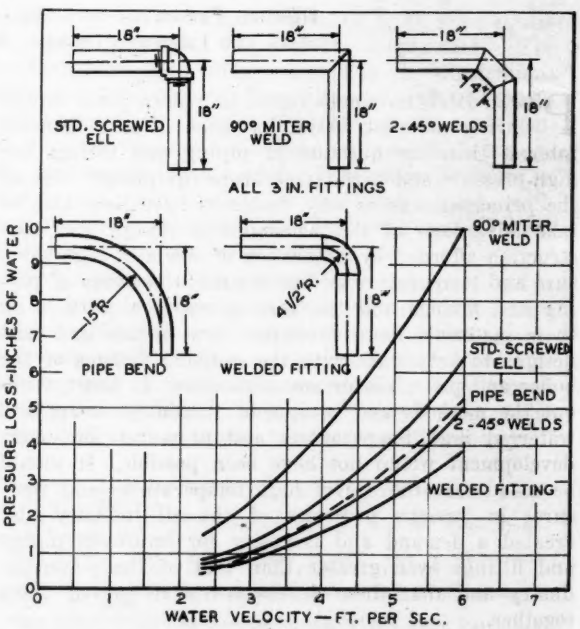


FIG. 3. COMPARISON OF PRESSURE LOSS ACROSS SEVERAL TYPES OF 3-IN. FITTINGS, FROM TESTS BY J. H. POUND, RICE INSTITUTE

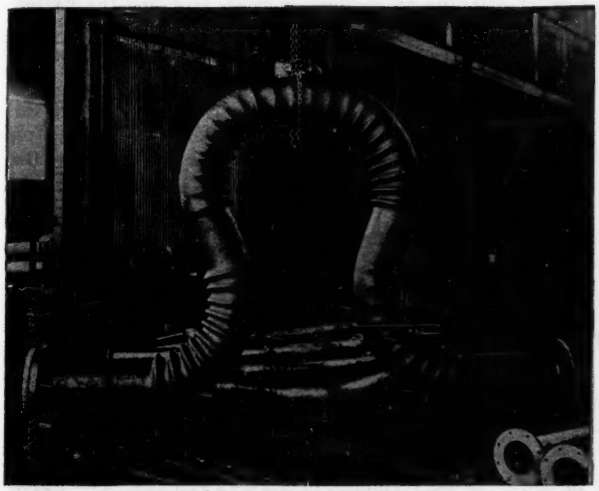


FIG. 4. CREASED EXPANSION BEND

large steam pumps, velocities must be kept low because of pulsating effect and vibration. For industrial heating process and drying work, higher velocities may be used.[3]

Expansion of piping must be taken care of in several ways. For low and moderate pressures, expansion joints are often used, including those in which one sleeve slides inside another and those in which corrugated expansion elements are employed. For high-pressure steam lines, in many cases, the inherent flexibility of the pipe is used by inserting bends, loops, turns and offsets in the lines. Expansion loops are common for this service and a recent development of this is the creased-bend, corrugated on the inside radius and designed to reduce the space required, as shown in Fig. 4.

Several types of flange joints are shown in Fig. 2, Figs. D and E being high-pressure joints. Another type of joint installed in many of the 1400-lb. piping systems is the Sarlun, a metal to metal joint, with long thin lips on the outer rim of the contact faces, these lips being welded to seal the joints.

For joints requiring gaskets, many reliable soft gaskets are available. Several improved types of metal and asbestos gaskets have been brought out.

Flow of water in pipes depends upon a number of factors such as the pressure loss permissible, pipe friction, condition of pipe interior and several others.[4]

Welded Piping

While screwed and flanged fittings are considered safe and reliable for the services for which they are designed, there has been a great interest during the last 10 yr. in fusion welding for installation of piping, valves, and fittings. The latter are now made in a variety of shapes and sizes for welding directly into the line. Headers are often fabricated by welding. Lengths of pipes are joined by butt welding. Bends, elbows, tees and other fittings are welded in place where desired, and many cases of large savings in cost of installation have been cited in favor of welded piping.

One of the principal advantages claimed for welded piping, in addition to reduction of weight, simplification of estimating, layout and erection, is lower first and maintenance costs. It must be remembered that welding jobs are designed somewhat different from those employing standard screwed fittings. The statement has been made that an oxyacetylene welded pipe line is lower in initial cost than a screwed line by at least 30 per cent and that maintenance cost is reduced about 80 per cent. An installation of 875 ft. of 16-in. steel pipe cost $3060 as compared with an estimate, including flanged work for $4304, showing a saving of about 37 per cent in favor of the welded pipe. Data on other welded piping installations show that these percentages are reasonable.

Development in insulation of piping during the past 10 years has been mostly in the working out of improved materials, methods of installing them and in the more accurate determination of heat losses from uninsulated surface and the ability of the various insula-

[3]See Calculating Steam Pipe Sizes and Pressure Losses. Power Plant Engineering, p. 8, January 1, 1931.

[4]See Capacity of Water Piping System, p. 14, Power Plant Engineering, January 1, 1931.

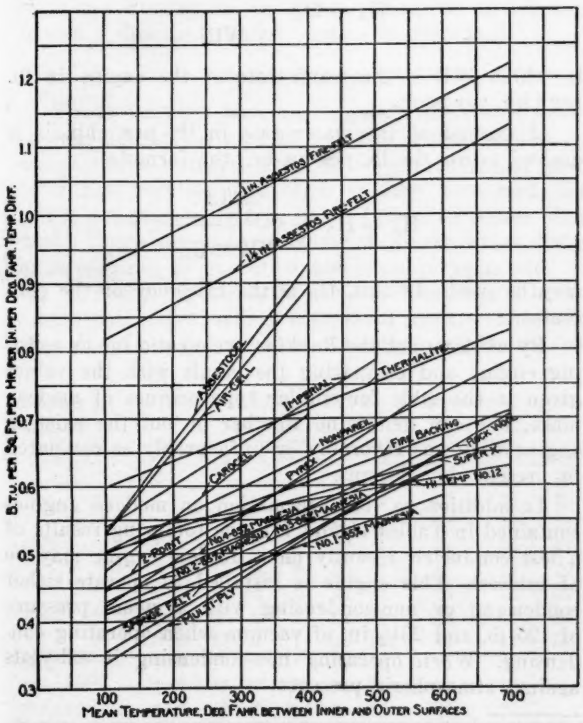


FIG. 5. HEAT CONDUCTIVITY VALUES FOR VARIOUS INSULATING MATERIALS

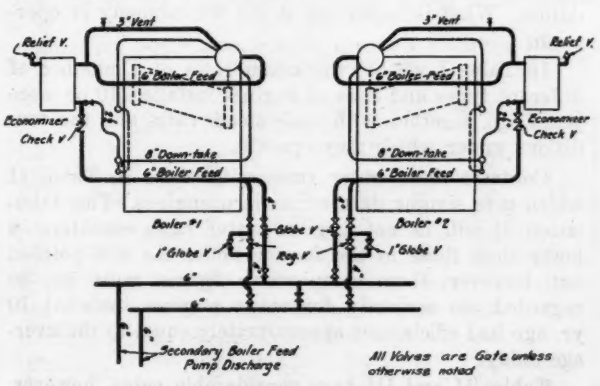


FIG. 6. FEEDWATER PIPING FOR 1400-LB. GILBERT STATION

tions to hold the heat in. Figure 5 shows typical heat conductivity values for a number of present-day insulating materials.

Piping Layout

Development of the past few years has been placing of main steam headers near the operating floor or on a gallery and leading all steam connections to these headers or manifolds so that valves would be easily accessible to the operators, eliminating the necessity of climbing on ladders or boxes to reach the valves.

In high-pressure steam piping, the tendency is to use as few traps as possible. Instead, many of these plants use drip and drainage systems, bringing all drips back to receivers equipped with drainage control devices. Where traps are required, however, either on high or low pressure lines, many types are on the market and in recent years they have been materially improved in mechanical structure to secure tightness, high capacity and freedom from dirt trouble.

Development in Power Generating Units

An Outline of the Major Developments and Improvements in Steam and Internal Combustion Engines, Steam Turbines and Electric Generators

IN CONSIDERING the development in the design and performance of the steam engine during the past ten or twelve years, it must be understood that this is not a long time in the life of a steam engine. Engines have undergone improvement during that period, indeed, the uniflow engine itself is only 12 to 15 yr. old in this country and it is the last real step in engine development; however, it does not fit into every plant by any means just because of its better efficiency because there are many other factors to consider. The life of a steam engine with reasonable care should be 20 to 30 yr.

During the past 10 or 15 yr., the heat efficiency of the steam engine has undergone considerable improvement and single cylinder units of the uniflow type are being operated with steam consumptions lower than those obtained from the older counterflow engines of the compound type. This does not necessarily imply that all counterflow engines can be scrapped and replaced with other types, for many of the older types have efficiencies which compare favorably with some of the more modern type.

Perhaps the best way of showing how engines available today compare with those of former years, is to present a list of engine performance of 10 or 15 yr. ago and then one showing the performance of some modern engines. As has been intimated, however, thermal economy is not the whole story of an engine; first cost, average maintenance, space considerations, also enter into the picture and all these factors should be kept in mind when considering the accompanying tabulations. What is important is the net economy of operation.

In Table I we list the steam rates of a number of different types and sizes of engines installed 10 or more years ago, together with their steam rates and the conditions under which they operate.

Contrast these water rates with those in Table II which give similar data on modern engines. This tabulation, it will be noted, gives water rates considerably lower than those in the former table. As was pointed out, however, these comparative figures must not be regarded too seriously for many engines installed 10 yr. ago had efficiencies approximately equal to the average today.

Tables II and III have considerable value, however, in that they provide one with a scale by which to measure the performance of his own engines. The Rankine cycle efficiencies, it will be noted, run from about 58 to as high as 92 per cent. The Rankine cycle efficiency is simply the ratio of the heat drop actually utilized to the adiabatic heat drop. In order to check the performance of any engine or turbine, the following formula for the Rankine ratio may be of interest

$$\text{Rankine ratio} = \frac{H_A - H_{B'}}{H_A - H_B}$$

In the formula, the terms in the denominator are obtained directly from a Mollier diagram*, H_A and H_B representing the total heat contents of the steam at the initial and final points on the expansion line of the engine. The numerator $H_A - H_{B'}$ may be obtained from the formula

$$H_A - H_{B'} = \frac{2545}{WR}$$

in which WR is the water rate of the engine in lb. per i.hp. per hour.

If instead of the water rate in lb. per i.hp. it is desired to use the lb. per kw-hr., the formula

$$H_A - H_{B'} = \frac{3412}{WR \times G_E}$$

may be used. In this, G_E is the efficiency of the generator.

By working out the Rankine cycle ratio for an existing engine and comparing the result with the values given in the table for similar type engines of modern make, one can determine whether or not the existing engine performs favorably or unfavorably as compared to present day designs.

In addition to the information on modern engines contained in Tables II and III, the following results of a test conducted recently on a uniflow engine may be of interest. This engine is installed to operate either condensing or non-condensing with a steam pressure of 125 lb. and 26½ in. of vacuum when operating condensing. When operating non-condensing it exhausts against atmospheric pressure.

*See Turbine Performance upon the Mollier Diagram, page 1095, November 15, 1931, issue.

TABLE I. TYPICAL PERFORMANCE DATA ON ENGINES PLACED IN SERVICE 10 OR MORE YEARS AGO

Type and Size Engine	Steam Pressure	Exhaust Pressure	Steam rate lb. per I.hp.	Steam rate lb. per kw.hr.
Tandem compound engine; high pressure, slide valve; low pressure, rotary valve. 100 kw.	94	Atmos.	31	83.8
Single cylinder riding cutoff piston valve engine, 200 kw.	102	Atmos	28.8	50.6
Single cylinder piston valve engine, 75 kw.	92	3 lb.	29.5	63.0
Single cylinder piston valve engine, 150 kw.	103	Atmos.	27.3	37.3
Single cylinder pressure plate valve, 100 kw.	125	Atmos.	23.9	69
Pressure plate valve engine, 75 kw.	105	2 lb.	31	84
Two valve uniflow with poppet valves, 150 kw.	132	Atmos.	26.5	42.6
Corliss non-releasing gear engines, 230 hp.	92	9.5	38.2*	
Corliss non-releasing gear engine, 140 hp.	95.5	5	45.5*	
Corliss non-releasing gear engine, 200 hp.	143	23		45.4

* Including boiler feed pump

Load Condensing	¼	½	¾	4/4	5/4
Steam per i.hp.....	13.1	13.3	14.3	15.8	16.9
Steam per kw-hr.....	27.6	23.5	23.8	24.6	26.2
Noncondensing:					
Steam per i.hp.....	17.2	17.2	18.5	19.3	21.2
Steam per kw-hr.....	36.6	30.4	29.9	29.9	32.3

These results were obtained with saturated steam. With superheated steam, of course, slightly better rates could be expected. At the present time, superheated steam is being used to an increasing extent in industrial plants—the average amount of superheat being about 100 deg. although some plants use 150 deg.

In still another test recently on a 300-hp. uniflow engine operating at 115 lb. steam pressure and 10 lb. back pressure, the water rate per i.hp. was 24.35 lb. per hr.

Performance of engines given in Table III on some modern uniflow engines—water rates as low as 9.35 and 8.7 lb. per i.hp. per hr. with a steam pressure of 250 lb. 200 deg. superheat and 26 in. of vacuum show what can be done with higher pressures and superheat and show the advance in the steam engine art so far as a properly designed uniflow engine is concerned.

Steam Turbines

Steam turbines have undergone considerable development during the past 10 yr. The central station operators have watched these developments rather carefully and have adapted them as they were made but this is not necessarily true in the industrial power plant field. There are many industrial plants which today have turbines in operation ten or more years old. In the majority of instances, such turbines could be replaced with more modern equipment more economically than they can be operated. In other words, the improvements in design and application made by the steam turbine manufacturers in the past ten years have made these old turbines obsolete and a liability except possibly for standby service.

During the past few years there has been considerable activity in the development of steam turbines to suit them to the requirements of the industrial plant better than the standard condensing and non-condensing units of the period prior to 1920. Today, condensing automatic bleeder turbines are being built to furnish bled steam for process work at constant pressures ranging from 2 to 200 lb. Some manufacturers build units of this type which are designed to run either bleeding or mixed pressure within the capacity of the unit so that should there be a surplus of process steam at any time, it can be taken care of in the low-pressure section of the turbine giving a certain amount of additional electrical energy. The demands of the industrial power plant have also brought about the development of the non-condensing bleeder turbine. This turbine furnishes bled steam at relatively high pressures as well as exhaust steam for process work. A third type of turbine developed particularly for the industrial power plant is the mixed pressure turbine. While this type of unit was developed prior to 1920, the last decade has seen its application to very special installations with marked success.

As has been implied, changing conditions of operation also cause existing turbines to become misfits. Typical changes of condition are as follows:

1. Addition of new boilers giving higher pressure and superheat.
2. Change in requirements for process steam requiring different pressure or quantity.
3. Change from condensing to noncondensing operation or vice versa.
4. Interconnection with Public Service lines or discontinuance of same.
5. Change in fuel cost.

On all steam turbines there has been a marked improvement of detail construction in order to improve the efficiency and reliability of the units. In Fig. 1 is given a curve which shows the increase in turbine efficiency during the period 1920 to 1930 of the machines of one manufacturer. While this curve applies primarily to the equipment of a particular manufacturer, this range of increase in performance is true generally of all machines.

This increased efficiency has been obtained principally by the refinement of steam parts, blading and

TABLE II. DATA ON MODERN TYPES OF STEAM ENGINES

Type, Size, and Operating Condition of Engine		Cylinder Dimensions Inches	I.hp.	Initial Press.	Back Press.	Full Load M.E.P.	R.P.M.	Lb. Dry Steam Per I.hp. per Hr.	Rankine Cycle Efficiency %	Lb. Dry Steam per Kw.-Hr.
				Lb. Gage						
Single Valve	100 Kw.	15 x 16 12 x 16	140 160	100 150	0 0	43.7 48.6	280 280	28.9 25.0	58.7 58.0	48.2 40.0
	500 Kw.	29 x 32 24 x 32	800 800	100 150	0 0	50.5 74.0	150 150	26.9 23.3	63.1 62.2	40.1 37.3
	100 Kw.	10 x 16 11 x 16	160 160	100 175	0 0	47.2 68.7	240 240	22.3 19.4	72.8 70.7	37.2 31.1
Four-Valve (Corliss)	300 Kw.	23 x 28 17 x 28	460 460	100 175	0 0	50.2 92.7	165 165	28.4 18.6	73.6 73.2	33.0 29.0
	750 Kw.	32 x 36 27 x 36	1200 1200	125 175	0 0	64.4 92.7	133 133	20.1 18.0	77.2 76.1	32.2 30.6
	100 Kw.	15 x 16 11 x 16	160 160	100 225	0 0	29.6 65.1	250 250	21.8 15.0	77.2 70.1	34.9 26.9
Poppet Valve (Uniflow)	300 Kw.	26 x 24 17 x 24	480 480	100 225	0 0	37.6 89.0	200 200	20.2 15.0	81.5 78.2	33.3 28.6
	750 Kw.	33 x 36 25 x 36	1200 1200	125 225	0 0	58.6 102.6	133 133	19.5 15.3	82.4 81.4	34.2 24.6
300-Kw. - simple Corliss		18 x 30	475	150*	0	82	150	21.7 ¢ L		65.6
300-Kw. - Uniflow		20 x 22	475	175*	0	68	300	19.6 ¢ L		67.7
300-Kw. - Uniflow		20 x 22	475	175*	26" V.	60	300	18.8 ¢ L	79	

*No moisture

TABLE III. PERFORMANCE OF MODERN ENGINES UNDER VARYING CONDITIONS

Type	Cyl.Bore & Stroke in Inches	I.HP.	Initial Press. of Superheat Back Press. or Vacuum	M.E.P.	R.P.M.	Net Lb. Per I.Hp.-Hr.	Rankine Cycle Efficiency %
9668 -	22x20	73	166-0-24.1	9.8	180	12.74	72.9
Emergency Fleet	"	283	161-0-23.8	38.5	119	14.27	66.2
Corp. -Horizontal	"	72	165-170°-24.9	10.58	181	11.33	77.5
Uniflow	"	314	168-350°-24.1	42.22	120	12.99	66.7
Steam-tight Poppet	"	75	163-118°-24.2	9.93	120	11.67	74.0
Valve Cam-actuating	"	290	164-109°-24.2	39.92	120	12.20	69.5
Gear.	"	82	166-154°-24.2	12.45	180	9.84	67.0
	"	333	161-158°-24.2	45.33	119	11.82	72.9
10346 -	24½x32	256	138-0° -0	28.5	125	17.9	68.8
American Locomotive	"	875	164-0° -0	30.5	124	16.8	64.2
Co. - Horizontal	"	298½	161-31° -0	33.4	125	16.4	69.0
Uniflow	"	309.5	168-101°-0	34.1	124	14.5	68.8
Steam-tight Poppet	"	284	169-136°-0	31.6	125	15.8	67.4
Valve Cam-actuating	"	256½	163-136°-26" V	29.8	124	10.2	77.6
Gear.							
11057 -	19x20	310½	250-200°-26½" V	40.3	93	8.70	78.9
11058 -	"	700	250-211°-26½" V	92.5	136	9.35	72.5
Standard Unit Navigation Co. - 3-Cylinder Vertical - Steam-tight Poppet Valve Cam-actuating Gear.							
10305 -	21x24	253	152- 0°-0	31.95	197	17.58	82.2
Teachers' College	"	190	156- 0°-0	23.90	198	17.74	81.6
Horizontal Uniflow	"	120	156- 0°-0	15.06	199	18.39	78.8
		311	156- 0°-0	39.20	197	17.70	81.7
Steam-tight Poppet Valve Cam-actuating Gear.							

nozzles and a more adequate test basis upon which to base design constants. It has been recognized that the steam passages through the blading and through the turbine cylinder must furnish the last possible obstruction for the steam. To this end some turbines are designed with a large number of steps in the turbine cylinder. Considerable attention has been given the design of the turbine cylinder with a view of reducing the cylinder distortions that accompany sudden changes of load, steam pressure, or steam temperature. As such distortions cannot be eliminated they have been minimized by the use of symmetrical cylinder design.

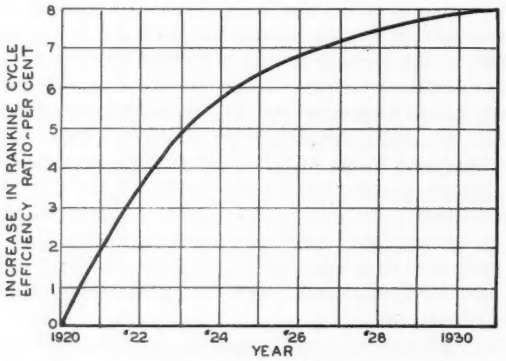


FIG. 1. INCREASE IN RANKINE CYCLE EFFICIENCY RATIO OF TURBINES FROM 1920 TO 1930

One of the greatest factors in making turbines purchased prior to 1920 obsolete has been the adoption of higher steam pressures and temperatures. Consider, for instance, a plant which has 150-lb. throttle pressure on the turbines. As may be noted from Fig. 2 there is a gain in heat available for work in the turbine of approximately 21 per cent if the pressure at the turbine throttle is increased to 450 lb. This gain is further based on the assumption that in either case all of the steam is expanded to 28 in. vacuum. Obviously an increase in pressure from 150 lb. to 450 lb. will require some additional heat in the boilers. On the basis of the same boiler efficiency the amount of additional heat required is shown by curve, Fig. 3. As noted, the amount of additional heat in a plant having no superheat from 150 to 450 lb. is only slightly over 1 per cent while the additional heat required in a plant for 200 deg. F. superheat at the higher steam pressure is approximately 2.75 per cent. A combination of the curves in Figs. 1 and 2 will give a fairly close approximation of the theoretical gain that can be made by increasing the steam pressure. As the steam temperatures have also increased with the pressures, an analysis has been made of the gain in available heat due to higher superheat. The curve in Fig. 4 shows the additional gain in available heat due to the increased superheat while Fig. 5 shows the additional heat required in the boiler and superheater. It will be noted that there is a net gain of approximately 2½ per cent because of the increased superheat. These curves were plotted directly from A.S.M.E. steam table data on the basis that the boilers, superheaters and turbines are not affected by the increased steam pressures and temperatures. The gain indicated, therefore, tends to be conservative.

There have been many mechanical improvements in turbines which do not reflect in a direct gain in efficiency. On turbines having relay governors, automatic nozzle control is now available. This means that the correct number of nozzles for best efficiency will always be in action. In many cases, automatic nozzle control can be applied to existing turbines.

Better governors are available which give both close and steady control; variable speed governors also have been perfected.

Diesel Engines

Although the development of the Diesel engine dates back as far as 1890, it is only in the past 10 to 15 yr. that this type of prime mover has really come into its own, particularly in this country. Not only has it been brought to practical technical perfection in that period but its field of application also was extended enormously. This is quite evident when the total horsepower of Diesel engine units made by American manufacturers is considered. Between 1920 and 1930, the total installed capacity of Diesel engines in this country increased from 2,000,000 to 6,000,000 hp.

The Diesel engine inherently has a high thermal efficiency and while there has been an increase in the efficiency of engines available today compared to those

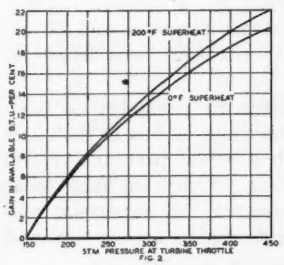


FIG. 2. GAIN IN AVAILABLE B.T.U. BY USE OF HIGHER STEAM PRESSURES

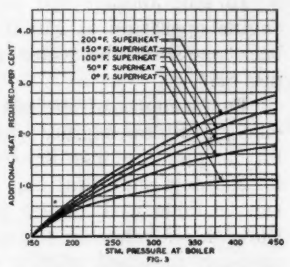


FIG. 3. ADDITIONAL HEAT REQUIRED BY BOILERS OPERATING AT HIGH STEAM PRESSURES

available ten years ago, this increase has not been as great as might be expected. In 1920, the average full load fuel consumption of Diesel engines was about 0.5 to 0.55 lb. per brake horsepower. Today, fair values per brake horsepower are as follows: full load 0.43; three-fourths load 0.44 and half load 0.52 lb. The best performance of modern engines will go as low as 0.4 or even lower. This, it will be seen, represents an increase in efficiency of over 20 per cent. While this represents a substantial increase in economy, it must not be inferred that all engines built ten years ago can be scrapped and replaced with new engines, for this is not so. As a matter of fact, there are many Diesel engines installed prior to 1920 which are operating today with fuel efficiencies not substantially lower than those of present day engines. Engines have, however, undergone great development in mechanical design, and from this standpoint alone it may be advisable to replace an old engine with a new one.

Since the Diesel engine of today has an efficiency which approaches quite closely the theoretical efficiency possible with this type of prime mover, there is not much reason to believe that present day engines will become

obsolete before the normal length of life has been reached.

During the last 10 yr., the greatest development in oil engine design has been in the development and perfection of the so-called "solid injection" or airless injection engine. Even these show marked variation in design and insofar as behavior is concerned, they may actually be divided into three classes on the basis of their combustion equipment. As a class, however, the performance of all solid injection engines may be considered on an equal basis, the difference in design having more to do with the matter of operation and maintenance than with thermal efficiency.

Throughout the entire decade we are considering, the Diesel engine has been subject to continual refinement and to continual increases in size. Marked advance has been made in standardizing not only the general design of the American Diesel which has been toward simplification of lines and centralization of control but also in the design of parts. Rotative speeds of 1000 r.p.m. and piston speeds of 1500 ft. per min. are not unusual in commercial applications.

Great advance has been made in the development and application of alloy materials and in precision manufacturing methods. Controlled pressure lubrication and more careful consideration of fuel injection methods and scavening have also contributed a great deal to the perfection of the modern engine. Noise due to exhaust or air intake has been mastered to such an extent that it is no longer necessary to be annoyed by such noises.

An important development in recent years has been that of the supercharger—a device for increasing the normal output at high altitudes. At high altitudes, an oil engine's failure to develop its sea-level rating is due solely to the dearth of oxygen in the light air. To develop more power, the engine must be supplied with more oxygen and the supercharger does this by precompression.

Engines have steadily become larger and the new high in size was reached recently when the city of Copenhagen awarded a contract for a double acting engine of 22,500 b-hp. for installation in a municipal plant.

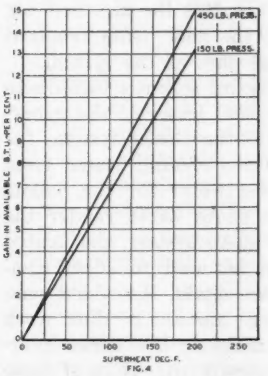
A feature of power plant practice that is receiving attention is the possibility of using oil engines in conjunction with steam engines to balance the heat and power output. Another important forward step in Diesel power plant practice during the year is the placing in service of a completely automatic Diesel electric plant supplying the entire requirements of a New York hotel. In this plant, the units start and stop automatically in accordance with the load—it requires practically no attendance.

Electric Generators

In considering the electric generator in the general scheme of rehabilitation with which we are concerned here, we must present a slightly different attitude of mind from that with which we have been considering other equipment in the plant. We must regard the generator not so much with the thought of improving its efficiency as with that of adapting it more effectively to the plant's needs.

Considered purely as a machine for converting mechanical energy into electrical energy, the electric generator is so nearly perfect that it has undergone relatively few changes in the past 10 yr. True, new methods of construction and design have been evolved which have resulted in a more effective use of material while improved methods of lubrication and ventilation have reduced the maintenance requirements but from the standpoint of efficiency the most recent generators differ only slightly from those built 10 or 15 yr. ago. By the use of new steels for the magnetic circuit and by the adoption of better insulating materials, the size has been reduced, but the efficiencies have been only slightly improved—not enough to warrant the replacement of an old unit by a new one.

Electric generator efficiencies vary largely, according to the size and speed of the machine; the higher the speed and the larger the capacity, the higher the full load efficiency. For this reason, turbine generators (because of their higher speed and usually their larger



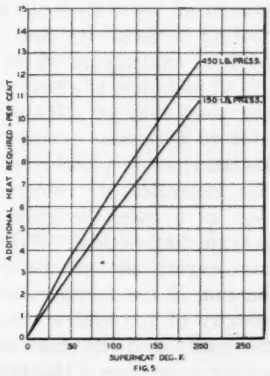


FIG. 4. ADDITIONAL GAIN IN AVAILABLE HEAT DUE TO USE OF SUPERHEAT

FIG. 5. ADDITIONAL HEAT REQUIRED IN THIS BOILER AND SUPERHEATER

size) have a higher efficiency than generators driven by reciprocating engines or hydraulic turbines.

In general, turbine-generator efficiencies vary from about 92.5 per cent on a 600-kw. unit to 95 per cent on a 5000-kw. unit at full load at 3600 r.p.m.; from 93.8 per cent on a 5000-kw. unit to 96 per cent on a 20,000-kw. unit at full load at 1800 r.p.m., and as high as 97 per cent or even higher for units in excess of 30,000 kw.

The efficiencies of engine driven generators are lower, first because of their lower speed and second because of their smaller size. A good 5-kw. direct current generator should have a full load efficiency of about 82 per cent; a 100-kw. machine about 91 per cent and a 1000-kw. machine about 93 per cent. Engine driven alternators have similar efficiencies.

In respects other than that of efficiency, generators have undergone considerable development. New steels with higher permeabilities, new insulating materials, new methods of winding and bracing, improved methods of ventilating and lubricating have all combined to make the generator of today a more reliable and a more compact machine than the unit of a decade ago.

It is from this standpoint of reliability and reduced maintenance rather than of efficiency that the generator must be regarded in any scheme of rehabilitation. In many instances the factor of reliability takes precedence over economy because reliability in the last analysis implies economy. It is of little consequence whether

a machine has a few per cent higher efficiency if, by virtue of this fact it is subject to failure, for the cost of the outages resulting from loss of production are liable to outweigh by far the savings effected by the higher efficiency.

One of the most notable advances in generator design in recent years has been the development of the 3600-r.p.m. alternator in large sizes. In this country, generators operating at this speed as large as 15,000 kw. have been built. This has brought about a reduction in space requirements for a given size machine and this, particularly in industrial plants, is often an item of considerable consequence.

Recent years also have witnessed great improvements in the ventilation of generators and in the removal of the heat generated in the windings. Today all turbine generators, practically, are provided with forced ventilation and in sizes over a thousand kilowatts, the closed system of ventilation is used. In this the air used for cooling is used over and over, the heat being removed by heat exchangers which form part of the system.

Application of these ventilating schemes introduces the possibility of utilizing the heat losses of the generator to a certain extent. With the closed system, for instance, it is possible to use the cooling water from the generator air coolers as feedwater for the boilers but, as a rule, the gain is so slight as to render the scheme impractical. With the open system, the heated air leaving the generator can be used to effect combustion in the furnaces but, here again, the added complexity of the system—the large amount of duct work necessary and the small gain, make such schemes interesting only from a theoretical viewpoint. Both of these methods of heat reclamation have been used in certain installations but have not come into general use.

The great advantage of the forced methods of ventilation of generators lies in the fact that machines can be operated at a considerably higher rating than they could with natural ventilation. The limiting condition of a generator is its temperature; therefore, any method which serves to carry off the heat generated in the windings more rapidly will result in an increase in the possible output of that particular machine. Modern large generators are absolutely dependent upon the forced ventilating system; indeed, if the supply of cooling air to a generator were interrupted for any length of time, the machine, by inability to radiate the heat produced in the windings, would soon result in heat to the point of destruction.

Besides increased speed and improved ventilation, many other developments have been made in generator design in the past ten years but most of them affect only the very large machines and for this reason they are not within the range of the average small or medium size power plant. Such developments as higher voltages, transposed windings, divided circuits have advantages only in machines having ratings upwards of say, 25,000 kv.a. As a matter of fact, these developments were made largely to overcome the limitations which ordinarily beset the design of generators of this size.

SHORT LIFE LAMPS may cost less per unit of light than long life because burned at higher intensity, i.e., more lumens per watt. Best economy is when maximum light is secured per dollar cost for current and lamps.

Condenser Performance Has Tripled

HIGHER VACUUM, MORE EFFECTIVE TUBE ARRANGEMENT, LOWER MAINTENANCE. IMPROVED AND BETTER AUXILIARIES CONTRIBUTE TO ADVANCE

IMPROVEMENTS in condenser and condenser auxiliary practice during the past ten years have been phenomenal but because of the interrelation of these developments and their somewhat indirect effect on the net station heat rate, it is difficult to isolate them and show their effect on plant economy.

Measured by what is perhaps the most obvious unit, the heat transfer coefficient as the B.t.u. transferred per hour per square foot per degree difference in temperature, condenser performance may be said to have tripled, increasing from about 200 to 600. Much of this improvement is due to better tube arrangement but a great deal is due to better construction, better maintenance[1] and improved auxiliaries.

These improvements benefit plant performance by reducing the vacuum, reducing the power absorbed by auxiliaries, reducing or eliminating the hotwell depression temperature and by reducing condenser circulating water leakage, which is often the source of boiler feed water troubles.

For new turbines, back pressures as low as ¾ in. absolute are used although 1 in. for central station and 1½ or 2 in. for industrial plants are what may be considered standard design practice. This is a decrease of about one inch over practice of a few years ago. Lowering the back pressure from 2 to ¾ in. absolute makes available approximately an additional 40 B.t.u. per lb. of steam, or roughly 10 kw. per thousand pounds of steam.

With any given turbine, an increase in vacuum means a decrease in the water rate up to a certain point. Beyond this the leaving loss becomes excessive and the water rate increases. This limits the use that can be made of improvements on existing turbines. It is true, however, that few turbines are operating at an average vacuum even approximating the correct value. This is particularly true of industrial plants where infrequent cleanings, dirt and scale lower the operating vacuum several inches. Rearrangement of tubes in old condensers is frequently effective in improving conditions. Such changes made in one old condenser increased the vacuum almost 1.5 in. of mercury.[2]

Condensers no longer consist of shells packed full of tubes. This rearrangement of surface has been effective in improving steam distribution, decreasing circulating water friction, equalizing pressure throughout the condenser, increasing condensate temperature and more effectively cooling the noncondensable gases handled by the vacuum pump.

Fewer joints, better machine work, welded shells and feedwater deaeration have decreased the air leakage. More effective air cooling sections, in some cases separate external sections, have reduced the volume of air to be handled. These, together with the improved efficiency

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[1]See Improving Plant Performance by Condenser Maintenance, Power Plant Engineering, p. 1035, Sept. 15, 1930; p. 293, Mar. 1, 1930, and p. 886, Sept. 1, 1931.

[2]See Improving Condenser Performance, Power Plant Engineering, p. 1055, Oct. 1, 1929.

of the steam jet vacuum pump and its wide spread application, have simplified the air removal problem.

Rearrangement of tubes, addition of external coolers at the vacuum pump suction or the addition of a low pressure steam jet booster preceding the existing present vacuum pump are effective methods of improving performance of existing units. Rolled tubes and the elimination of ferrules has also done much to decrease water friction and tube corrosion due to air entrainment. It is now possible to obtain special bushings so that rolled tubes can be used on old tube sheets.[1]

Circulating water velocities have been increased from about 4 or 5 to a maximum of 10 or 11 ft. per sec. Heat transfer increases approximately as the square of the velocity and even though the friction is greatly increased the reduction in shell size is worth the additional loss of pumping head in many cases. Tubes of muntz, admiralty, brass, copper and special metals are now available in all sizes to meet special conditions where corrosion is bad. Chemical, sand blast, rubber plug and scraper methods of tube cleaning are now highly developed. The most recent advance is the use of chlorine to kill algae, a troublesome feature in many plants using cooling water contaminated by sewage.

Two effective examples of improved condenser design and practice are offered by Lakeside and Hell Gate stations. As explained in the Lakeside article, p. 831, August 15, 1931, the contrast between units Nos. 5 and 6 is striking. Both are 50,000-kw. turbines. No. 5 was installed in 1925 with a 50,000-sq. ft. condenser. Number 6 was installed the next year with a condenser of advanced design with one-half the surface, 25,000 sq. ft. In the tabulation of Hell Gate Station on p. 800, Aug. 1, 1931, a history of condenser design over a period of 10 yr. is given. In 1921 a 50,000-sq. ft. condenser was installed under a 40,000-kw. turbine. In 1929, a 137,000-sq. ft. condenser was installed under a 160,000-kw. turbine. This is a change from 1.25 to 0.86 sq. ft. per kw. of capacity. More extreme cases can be cited but these two represent improvements in the same station under the same load and water conditions, in each case, by the same engineer and manufacturers.

Exact performance of the condenser can be calculated from the water rate of the turbine, throttle steam conditions, condenser pressure and water temperatures. Assuming 1000 B.t.u. as the average heat content of exhaust steam and 8⅓ lb. as the weight of a gallon of water, the following formulas give the approximate performance or requirements.

$$C = \frac{WH}{ST_D} = \frac{950W}{ST_D} \quad (1)$$

$$G = 2W \div T_R \quad (2)$$

$$V = 0.321G \div AN \quad (3)$$

Where

C = Coef. of heat transfer B.t.u. per sq. ft. per hr. per degree F. temperature difference

W = pounds of steam per hour

H = B.t.u. absorbed in condenser per pound of steam. Equal to heat at throttle less the heat converted to work, radiation losses and heat in condensate. Assumed = 1000 for approximate calculations.

S = condenser surface in square feet.

T_D = mean temperature difference in degrees F.

G = circulating water in gallons per minute.

T_R = rise in water temperature in degrees F.

V = water velocity in feet per second.

A = internal area of one tube in square inches.

N = number of tubes per pass.

With these formulas, it is possible to find out what any condenser is doing and determine whether it is up to standard. Practical standards for all sizes of modern units can be determined from a study of the condenser tabulation to be found in the December 15 issues for the past several years.

Improvements in Switching Equipment

DEION AND AIR BLAST CIRCUIT BREAKERS, AS WELL AS NEW DESIGN OF METERS AND INSTRUMENTS, FURNISH OPPORTUNITY FOR IMPROVEMENT

RECENT YEARS have witnessed many changes in electrical switching equipment not only from the standpoint of design but also in the service requirements demanded of the equipment. Changes in voltages used, increases in the capacity of circuits, higher standard, in the demand for reliability, all have exerted an important influence upon the character of the switching apparatus used in the circuits. More and more, as voltages and capacities increased, the demands upon switching equipment have become more rigid and more exacting until today, the specifications for a large oil circuit breaker are of as complex and technical a nature as those of a more "productive" piece of electrical equipment; for, after all, a switch in itself contributes nothing to the efficiency of the system—it produces nothing, for it is merely a device to open or close an electric circuit.

If it were not for the fact that switches must open and close while electric energy is flowing through the circuit, there would be no problems connected with the design of switches. A switch, however, must be compared to a clutch between two rotating mechanical systems. To connect one system to the other, it is necessary to do so with the least amount of disturbance and shock to either system and yet do it rapidly. In case of trouble on a circuit, that is, a short circuit or a ground, the safety of the equipment on the circuit depends upon the effectiveness of the circuit breakers—upon the rapidity with which they open the circuit; thus modern circuit breakers are rated according to the speed at which they can interrupt given amounts of current at specified voltages.

Because of the increased demands made upon switches and circuit breakers in recent years, they have been subjected to much development and refinement. The common open, knife switch of the early days has been superseded by enclosed air and oil circuit breakers and in the larger sizes their design is based upon highly

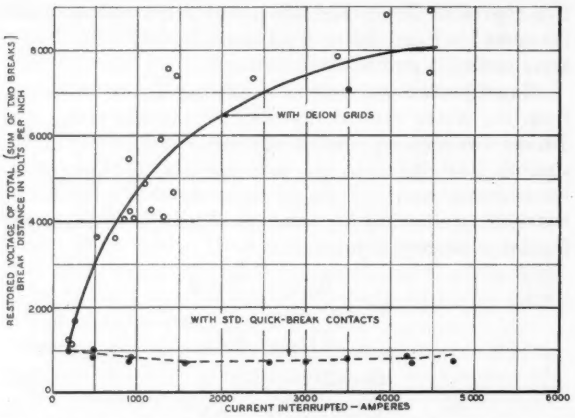


FIG. 1. RELATIONSHIP OF CURRENT INTERRUPTED TO RESTORED VOLTS (R.M.S.) PER INCH OF DISTANCE IN AN OIL CIRCUIT BREAKER WHEN EQUIPPED WITH QUICK BREAK CONTACTS AND WITH DEION GRIDS

theoretical considerations; thus, in the design of the so-called deion circuit breaker, the design is the result of a highly developed theory of ionization between arc terminals.

Aside from the circuit breaker proper, that is, that part of the apparatus which actually breaks the circuit, new types of control and protective circuits have been developed. The circuits, though intended for the protection of other electrical equipment, operate in conjunction with the circuit breaker, since it is the circuit breaker that finally opens the circuit in time of trouble.

Because of the increases in capacity of circuits and connected apparatus and of increases in voltage, it is possible that switching equipment installed ten or more years ago, today is inadequate to protect the system properly. True, it may function with perfect satisfaction under normal current and voltage conditions but the question is whether it will function properly at a time when most depends upon its doing so, that is in a case of short circuit or ground. In order, therefore, to determine whether or not a certain switch is inadequate it is necessary to be able to determine with some degree of accuracy the short circuit current which will flow under abnormal conditions.

This may be determined by either of three ways, namely, test, calculation or assumption. An actual test in most instances is out of the question, first because of the danger to the system involved and second because of the expensive and elaborate apparatus necessary.

The procedure involved in calculating the short circuit values is not difficult but is somewhat lengthy and for this reason a detailed description cannot be given here. It involves the preparation of a single line diagram of the system, the determination of the reactance constants and the solution of the network in terms of these reactances.

Because of the many varieties of switches and circuit breakers, it is rather difficult to give a classification of switches with respect to one feature alone, without the overlapping of several other characteristics.

As a rule, modern practice permits the use of knife switches on circuits up to 550 v., both alternating and direct current. These may be either of the open or safety enclosed type. On switchboards in power plants where those fully familiar with electrical equipment are in attendance, the open knife switch is perfectly satisfactory for such voltages; but in industrial plants or in parts of the power plant where the switches are subject to operation by less experienced help, the safety enclosed type of switch has many things in its favor.

On circuits above 550 v., particularly on alternating current, oil switches or oil circuit breakers are generally used. The voltage and continuous current ratings have been fairly well standardized and for any given voltage rating there are several current ratings available.

Among the developments in circuit breaker design, one of the most important is that of the deion circuit breaker. This development marked the completion of an extended research into the fundamental nature of the electric arc, by a group of engineers, and is based on the fact that a very thin layer of gas immediately adjacent to the cathode is deionized much more rapidly than other portions of the arc. The development, therefore, consisted in designing a circuit breaker in which all portions of the arc are brought in close proximity to a cathode surface, thus bringing about a rapid deionizing action which results in extinguishing the arc.

In the actual breaker, this principle is incorporated in the form of a deion grid, a complex structure of metal and insulated plates into which the arc formed by the opening of the breaker is blown. The theory and development was fully described in articles in Power Plant Engineering so that it is not necessary to explain it in great detail here[3]. In the original development of this breaker, the principle was applied only to air circuit breakers but with the development of the grid unit, its application was extended to the oil circuit breaker as well. Today, they are available in a variety of sizes and types from small units handling a few amperes to others capable of interrupting well over a million kv.a.

[3]The Deion Breaker, March 15, 1929 issue, p. 353. Using Gas for Arc Rupture, March 15, 1930 issue, p. 345.

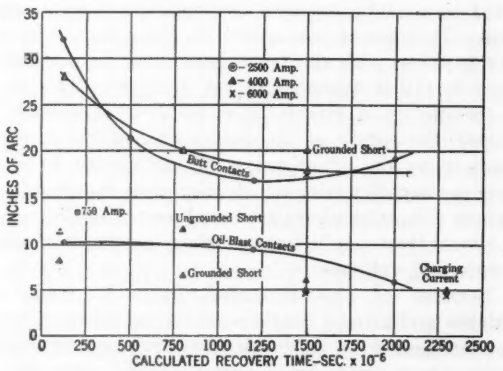


FIG. 2. TESTS AT PHILO OF OIL CIRCUIT BREAKERS SHOWING THE MAXIMUM ARC LENGTH VS. RECOVERY TIME

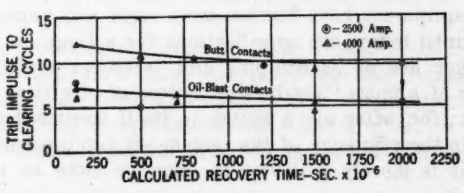


FIG. 3. TESTS AT PHILO OF OIL CIRCUIT BREAKERS SHOWING THE DURATION OF SHORT CIRCUIT VS. RECOVERY TIME

Figure 1 shows the effectiveness of this type of breaker as compared with conventional types of breakers. These deion grids can be adapted to old type oil circuit breakers with considerable effectiveness.

Another recent development in circuit breaker design is the oil blast breaker[4]. In this type of breaker the circuit is broken under oil in a closely confined space and the gases so produced are made to sweep across the arc, thus extinguishing it. The ultimate theory of this breaker is not clear but it is probably bound up with the deion theory. Its effectiveness, however, has been demonstrated and this type of circuit breaker, undoubtedly, has wide application on all types of circuits. In Figs. 2 and 3 are shown curves which indicate the performance of this type of breaker as compared to those having ordinary butt contacts.

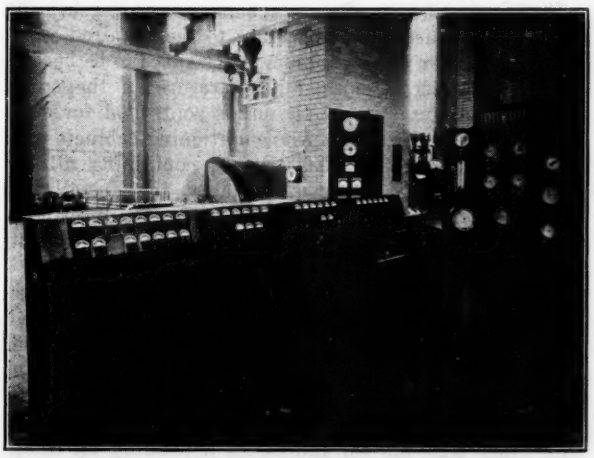


FIG. 4. ELECTRICAL CONTROL BOARD AT BREMO STATION SHOWING COMPACT MINIATURE INSTRUMENT PANEL

Aside from the improvements in the design of switches and circuit breakers proper, there have been many developments in associated equipment, that is in protective and metering equipment. Instruments have been greatly improved, not only as regards accuracy and reliability but as to size and external design. For one thing, they have been made smaller so that a larger number of them can be mounted in a given space and within range of an operator's vision. Where expansion of the electrical facilities is necessary but where space is at a premium, these smaller instruments together with more compact control switches which are available, have many advantages.[5]

In planning the rehabilitation of a plant, the possibility of utilizing some of the newer and improved systems of electrical protection should not be overlooked, especially from the standpoint of reliability.

The question of protection of a piece of electrical equipment is largely a question of its relative importance to continuous service. Machines which are installed in duplicate, for instance, do not necessarily require the same high degree of protection that is necessary where only one machine is installed or where two or more machines are required to operate continuously. At the same time, it is also dependent upon the characteristics of the machine itself.

Switchboards have undergone great development in the past ten years. More and more use is being made of the steel front switchboard. Steel has the advantage of lightness and strength, making easy handling of complete panels in one section. Framework and fittings as well as finish have been worked out to allow good matching of steel panels in one part of the board with other panels of slate or ebony asbestos where needed for mounting knife switches and air circuit breakers.

General progress in design has been toward increasing compactness, reducing the width to a minimum without over-crowding. This has been facilitated by improvements in design of apparatus, a notable example being the rectangular types of instruments and meters, which make the most complete use of the panel space occupied. The length of the switchboard is usually dependent on the oil circuit breakers used, if these are mounted directly back of the panels. If the breakers are remote mounted and particularly if they are electrically operated, greater advantages may be taken of economies in space occupied by the panel-mounted equipment with resulting increased compactness and convenience to the operator.

Advance in Transformer Equipment

LARGER UNITS, NEW METHODS OF COOLING, USE OF NEW MATERIALS AND APPLICATION OF RATIO ADJUSTERS, ARE IMPORTANT DEVELOPMENTS

DEVELOPMENT IN TRANSFORMER equipment in recent years has been directed largely to the production of units of higher capacity per unit volume and to designs which permit changing the voltage ratio under load. Designs for use on higher voltages also have been developed and these have been further refined by making them nonresonating.

In the small plant where the units are of moderate size and where they are connected to relatively short lines, the last feature is of relatively little importance but in large units connected to long high-voltage transmission lines, the nonresonating feature has been of the utmost importance. In this type of transformer, the capacitance charging currents of the various elements of the winding to ground are supplied by means exterior to the winding, i.e., by metallic shields placed outside the coils. With this arrangement, no charging current for the coils to ground passes through the inductance of the coils, so that the voltage drop across any of the coils is a constant, independent of frequency. This method of construction greatly reduces the stresses imposed on the unit during lightning surges.

In small transformers as well as in large ones, considerable advance has been made in developing units with greater capacity per unit volume. New transformer steels with higher permeabilities and lower losses, new methods of design, better insulating materials, improvements in methods of cooling, all have contributed to this trend.

Methods of cooling in particular have been subject to considerable development with a consequent decrease in unit volume. Since the temperature rise in various

[4]New Oil Blast Circuit Breaker Is Effective, p. 363, March 15, 1931, Issue.

[5]The Industrial Switchboard of Today, Parts I and II, Sept. 15 and Oct. 1, 1930, Issues.

parts of a transformer determines the safe load it will carry, it is evident that any method by which this temperature can be kept down will bring about an increase in capacity.

In general, three methods of cooling are in use—self-cooling, water-cooling and air-blast cooling. Of the three methods, the air blast method seems to be the most effective. In this method, the convection air currents present in the self-cooled transformer are supplemented by small air jets impinging on the radiating surface of radiators, tubes or corrugations, the air being supplied by blowers. By this method, the heat dissipated from the oil is approximately doubled for the same temperature rise. Also, the convection currents in the oil are increased, resulting in a faster oil flow and lower temperature. The method of supplying the air jets has been standardized and consists of an air chamber located directly behind the radiators and attached to the main transformer tank. Removable air distribution pipes connected to this chamber release the air in jets upwards along the surface of the radiators.

One-half horsepower per 100 kv-a. of increase in transformer output over the self-cooled rating is all that is necessary to operate the blower, delivering air at about 3 oz. pressure. The air jet transformer as a rule will have a self-cooled rating approaching 60 to 70 per cent of the air jet rating.

From this it is quite evident that by merely adding forced air cooling to a transformer arranged only for self-cooling, the capacity of the installation can be materially increased. This possibility should not be overlooked in any plan for rehabilitation for instead of replacing present transformers with larger units, it may only be necessary to add the air blast equipment.

To show the effectiveness of this method of cooling, the three following conditions are given for a 5000 kv-a., 13,200 v., 60-cycle, 55 deg. C. transformer:

	Water-cooled	Self-cooled	Air Blast
Floor dimensions, in inches	82 x 76	93 x 95	51 x 40
Floor space, square inches	5530	7900	2040
Weight in lbs.	31,500	35,000	19,500
Full load efficiency, per cent	99.2	99.2	98.9
Approximate price, per cent	100	115	107

On the whole, transformer efficiencies have not increased materially during the past 10 yr. The alternating current transformer is perhaps the most efficient device designed by man, having efficiencies well over 97 per cent even in small units, but running as high as 99.7 per cent and even higher in larger units. For this reason, little is to be gained by the replacement of one transformer by another merely because its full load efficiency is a trifle higher.

What is more to the point is to determine the proper loading for a transformer bank. The efficiency of a transformer varies considerably over the load range and unless transformers are used at or near the high point on the efficiency curve, the cost of operation will be higher.

A most important development in transformer practice in recent years is that of the so-called ratio adjusters or tap-changing devices which permit the changing of the voltage ratio of the transformer under load. These are used on practically all large transformers these days and their use has materially improved operation.

Although there is no well defined boundary between power and distribution transformers as made at present, there are a few differences. Power transformers are usually built in larger capacities and higher voltages than distribution transformers. The distribution type being continually connected to a distribution system will show a higher all-day efficiency if the core loss is small. This is done by special design, usually at the expense of increased copper loss. Usually in distribution transformers, the core loss is about one half of the copper loss, or one third of the total.

Heating Changes to Air Conditioning in 10 yr.

Air conditioning equipment[1] consists essentially of a fan blowing air through spray washers that clean and dehumidify it, after which it passes over heating coils, which raise its temperature to the required value for transmission through ducts to the space to be heated. By using water at proper temperature in the spray washers, the humidity of the air is controlled for summer or winter operation. Air conditioning cabinets with capacities as high as 10,000 c.f.m. containing all the above elements are now available for installation directly in rooms to be conditioned. Water for sprays can be cooled by refrigeration or more directly by melting ice.

The heating codes of various states usually specify the amount of fresh air that must be introduced, varying between 2.0 c.f.m. per sq. ft. of floor area for certain rooms in schools to 4.0 c.f.m. for kitchens. Many of the state codes specify 1800 cu. ft. of fresh air an hour at 70 deg. for each pupil in a school and other amounts for industries depending on conditions.

Unit heaters consist of a heating element enclosed in a casing, with motor driven fans to draw or blow air over the element, which may be heated by steam or, for cooling, may contain brine or cold water. These unit heaters or coolers are mounted directly in the room to be heated or cooled. Some models are suspended from wall or ceiling, some rest on the floor; others are installed in walls or under windows. While direct steam radiators are often rated at 240 B.t.u. per sq. ft. heat emission (sometimes less when the surface is in coils), radiation per square foot for unit heaters is usually much higher because of convection. Various manufacturers supply them rated from about 100 sq. ft. of direct radiation to several thousand square feet and for heat emissions ranging between 20,000 B.t.u. per hr. for some of the small units up to 2,000,000 B.t.u. per hr. for the large floor types. Unit heaters may also be obtained for direct firing by coal, coke, wood, gas or oil. Proper spacing and location of unit heaters are necessary for best results. Owing to their flexibility of installation, they lend themselves well to heating of large industrial buildings.[2]

Extended heating surfaces are frequently used not only for unit heaters but for direct radiation as well. These surfaces consist usually of tubing on which square or round fins are fastened by various processes to give a total surface often 15 times that of the original tube.

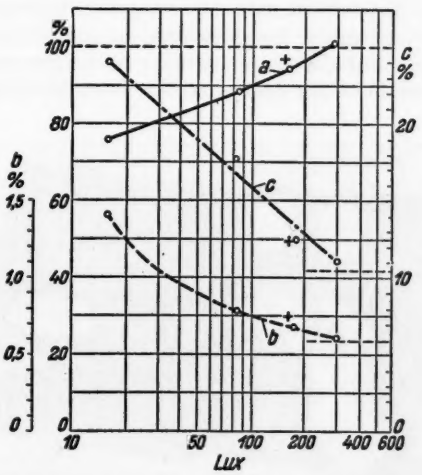
[1]Make the Climate Fit Your Process, Power Plant Engineering, page 190, Feb. 1, 1929.

[2]Locating Unit Heaters in Industrial Buildings, by Charles L. Hubbard, Power Plant Engineering, page 1237, Nov. 1, 1930.

Development in Plant Lighting Equipment

PROPER ILLUMINATION INTENSITIES TODAY ARE CONSIDERABLY HIGHER THAN THEY WERE TEN YEARS AGO

GOOD INDUSTRIAL illumination has a direct bearing on production and upon the prevention of accidents. While this fact is almost self-evident, it was not until quite recently that it has been generally recognized and that any serious attempt was made to provide adequate illumination in industrial plants. New lighting equipment also has been developed which has made possible much better illumination than could be obtained with older equipment. Because of this it is well to consider the lighting system critically to determine whether



a = Output in % of that by daylight, *b* = Compositors errors in % of *a*, *c* = Letters reversed in % of *b*, ——— values for natural daylight (300 Lux), + values for artificial daylight (170 Lux) for *a*, *b* and *c*.

FIG. 1. INCREASE OF OUTPUT BY INCREASING THE ILLUMINATION. EXAMPLE FROM A PRINTING PLANT

or not it may be improved, for sometimes it is possible to effect startling savings in this way. The added cost of modern high intensity illumination is small compared to the gains in production and the savings in maintenance that might result from its installation.

Indeed, it is claimed by those who have investigated this question that every dollar invested by a manufacturer for improved industrial lighting brings an annual return of $34.

In Fig. 1 is given a chart which shows the increase in productive output by increasing the illumination in a printing plant. As the lighting intensity increases, the percentage of output increases and the percentage of reversed letters compared to the errors, decreases.

Hand in hand with development in lamps and fixtures, there has been considerable development in methods of wiring and design of lighting distribution systems. In the early days, little attention was given the lighting distribution system of a plant; as a rule, open wiring was run from a system of vertical feeders to wherever a source of light was required. Such systems naturally were not flexible and with the types of lamps and fixtures available were quite inadequate in the light of present day developments.

Tapping existing circuits for additional lighting units and increasing the lamp wattage throughout does not always remedy the situation. Instead, it can make conditions worse. The power required for additional units and the increased lamp wattages quite frequently overload the lines, causing excessive voltage decrease. A slight decrease in voltage results in a great decrease in illumination. In Fig. 2, for instance, it is seen that a decrease of 3 per cent in voltage reduces the light output of a Mazda lamp more than ten per cent.

Rewiring and reallocation of outlets and switches is the only solution to provide a satisfactory lighting installation where the old system is inadequate.

Today, a system of wiring has to be extremely flexible to meet the constant changes and additions to equipment as floor layouts are rearranged. At times, also, foot candles have to be increased to make up for the increased depreciation due to smoke, dirt or fumes.

Because of the great progress in illuminating engineering and lighting design, lighting systems which were thought adequate ten years ago are hopelessly inadequate today. In the accompanying tabulation are shown recommended illumination intensities of today as compared to those in common use ten years ago. From

ILLUMINATION INTENSITIES RECOMMENDED TODAY COMPARED TO THOSE USED 10 YEARS AGO

Class of Work	Foot Candle Intensity in common use in 1920		Foot Candle Intensity recommended today	
	Good Practice	Minimum	Good Practice	Minimum
Aisles, stairways, passageways	0.70	0.35	3	2
Rough Manufacturing Operations	3.5	1.7	10	5
Fine Manufacturing Operations	6.0	3.5	25	6
Fine bench and machine work			20	12
Light colored textiles			10	6
Tobacco manufacture			25	15
Tool making			20	12
Special fine work	15.	8.		
Engraving			50-100	25
Drafting			25	15
Motor manufacture			20	12
Jewelry and watch making			50-100	25
Dark textiles			20	10
Office work	6.	3.5	15	8

this table it will be seen that the recommended illumination intensities of today are from three to six times as high as was common practice in 1920.

Such high illumination intensities are easily attained today by the use of modern lighting equipment. New types of reflectors have been developed which give almost any conceivable distribution of light and by the use of high wattage lamps in such reflectors, any desired intensity of illumination can be secured over any desired area.

Modern incandescent lamps are substantially more efficient than those of ten years ago, as may be noted from the following tabulation which shows the lumen

output of Mazda lamps, as given in the bulletins of the National Lamp Works of the General Electric Co. for 1921 and 1931 respectively.

LUMEN OUTPUT OF MAZDA LAMPS

	1921			1931		
	110-125 v. standard service	110-125 v. daylight Mazda	220-250 v. standard	110-120 v. standard	110-120 v. daylight Mazda	220-250 v. standard
100	1260	875	995	1350	900	1040
150	2040	1400		2300	1500	
200	3100	2000	2520	3200	2100	2700
300	4840	3360	4100	5300	3500	4300
500	8750	5600	7850	9500	6200	8100
750	13,900			14,800		13,000
1000	19,300		17,500	21,000		27,300

From this table it is evident that, particularly in the larger sizes, modern incandescent lamps are considerably more efficient than those of 10 yr. ago, permitting

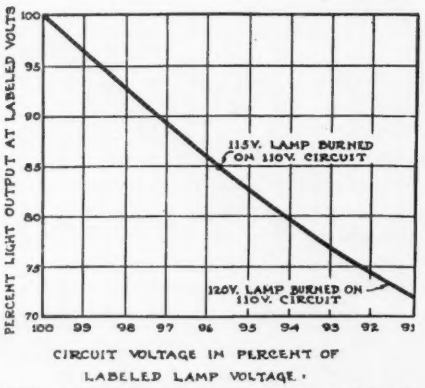


FIG. 2. OVERLOADED CIRCUITS CAUSE VOLTAGE DROP AND REDUCED LIGHT OUTPUT

a higher illumination intensity without an increase in current consumption. In addition to the increased efficiency of lamps, other improvements have been made—one in particular being the development of inside frosting. The advantages of frosting an incandescent lamp on the inside of the bulb have been realized for many years, but until recently no satisfactory method had been devised. It is obvious that a lamp with a smooth outer surface will stay clean longer than one with a roughened outer surface. At the same time, the use of frosted bulbs as compared with clear bulbs is naturally to be preferred, as with the former type the eye is shielded from the intense brightness of the filament.

Among the more recent developments in lighting control equipment is the automatic photo-cell switch which automatically switches on the lights when daylight falls below a predetermined intensity and extinguishes them as natural illumination increases above this value.

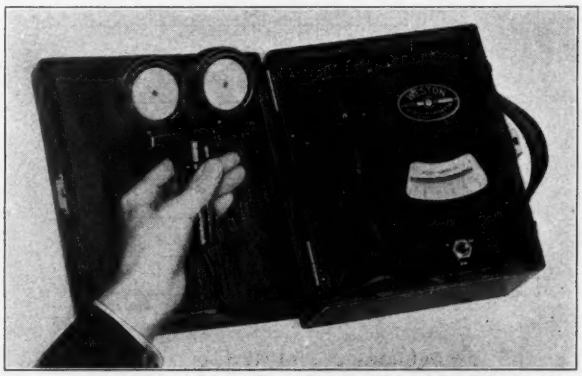
In looking toward the improvement of a lighting system, the effect of dirt and dust on a lamp must not be overlooked. Speaking before a group of engineers recently, Ward Harrison, director of the National Lamp Works, said that the average level of illumination in the United States would be doubled at once if all the lighting equipments were washed today. The illumination furnished by a new lighting installation is from 25 to 50 per cent higher than the average illumination furnished by the same installation after it has been in service for some length of time, due to the collection of dust and dirt on the lamp and equipment. While it is impossible to keep the equipment in its original dust free condition, it is possible to keep it reasonably clean. A record should be kept of the foot candle intensities in various points of the plant, by means of the foot candle meter. As soon as lighting intensities fall below established levels, the reason should be determined and the intensity restored.

Measuring Light Directly

RECENTLY an instrument has been developed which reads illumination intensities with ease and facility, by the Weston Electrical Instrument Corp. of Newark, N. J., and is known as Model 603 Illuminometer.

On the end of a flexible cord is a light target that may be placed in any position. This light target or searching unit has two Photronic cell units which convert light energy directly into electrical energy without the use of batteries or other auxiliary voltage, maintain constant output over long periods of time and have considerable output, thus allowing the use of a rugged portable instrument calibrated directly in foot-candles.

The instrument has three ranges, namely 10, 50 and 250 foot-candles, a range changing switch providing for the selection of the desired scale. The light target may



be placed at positions so that shadows or lights reflecting from light clothing will cause no error in readings. Light may be read from all angles and the light target may be placed in relatively inaccessible places, such as show cases or windows. Absorption of light by painted walls, screens and draperies can be measured directly by turning the light target so that it faces to or away from the surface.

Because readings may be taken quickly and accurately, the time required to make a lighting survey is greatly reduced.

PRODUCTION of electricity by the electric light and power industry of the United States for the week ended Saturday, November 28, was 1,599,900,000 kw-hr., according to the National Electric Light Association. The Atlantic seaboard shows a decrease of 1.4 per cent from the corresponding week last year although New England, taken alone, shows no change from 1930.

The central industrial region, outlined by Buffalo, Pittsburgh, Cincinnati, St. Louis and Milwaukee, registers, as a whole, a decrease of 8.2 per cent, while the Chicago district, alone, shows a decrease of 7.0 per cent. The Pacific Coast shows a decline of 2.4 per cent below last year.

Plant Electrical Equipment

Methods of Balancing Circuits, Improving Power Factor, Practice in Regard to Voltage Regulation and Load Control

CONSIDERATION of the plant electrical equipment involves a study of several more or less independent factors. First, for instance, there is the electrical distribution system. This may be considered as comprising everything between the power station switchboard, or the incoming power panel of the public service company, and the control device of each individual piece of electrical equipment in the plant; thus, it includes all overhead or underground, inside and outside wiring, all transformers, all switching and substations and all protective equipment installed on the lines. Next, we have the control devices themselves. These include all starting switches, both manual and automatic, all speed and temperature regulating equipment, and all protective equipment and all metering equipment connected

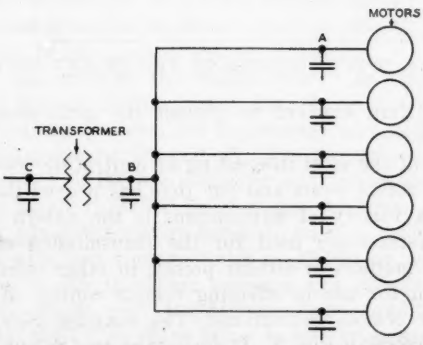


FIG. 1. THREE POINTS FOR THE APPLICATION OF CAPACITORS ON AN ELECTRICAL CIRCUIT

to individual pieces of equipment. Finally, we may consider the power using equipment itself, the motors, the heaters, lighting equipment, etc.

In general, there has been no fundamental change in the design of distribution systems in the last decade or so, except that more modern equipment has been evolved which permits of greater flexibility. With the development of alternating current motors with better speed control characteristics, there has been an increase in the use of alternating current distribution systems; indeed, except in certain special cases very few new direct current systems are being installed. In many plants where direct current generators were installed originally, these systems are still in use and where they are they continue to give excellent service.

In the operation of an electrical distribution system, the principal consideration, exclusive of the fact that the conductors must be of sufficient capacity to carry the required current without excessive voltage drop, is that the system be balanced. This applies both to the three-wire Edison direct system and to two and three phase alternating current systems. To do this, a careful survey should be made of all equipment on each circuit, and by comparing the total power load connected to each circuit any unbalance that may exist will be made evident. In a study of this kind, however, care must be taken to consider the use factor of each equipment. For instance, a tabulation of the rated power consumption of all equipment connected to a certain system might show a balanced condition, yet if half of the equipment on one circuit was in use only a half or quarter of the total time that the equipment on another circuit was used, it is quite obvious that the circuit would not be balanced.

In balancing single phase 3 wire circuits, the use of small air-cooled balance coils will be found advantageous. These are auto transformers furnishing 115 v. from 230 v. mains or vice versa. They derive a 230/115 v. 3 wire service from a 230 v. supply.

After a system has been balanced, the voltage drop over the various circuits should be determined. In the case of lighting systems this should not exceed 3 or 4 per cent between the incoming line proper and the lamps. On motor circuits larger drops are allowable, usually about 8 per cent. If the circuit is used both for lighting and power service, the 4 per cent drop in voltage is the limit.

Power Factor Correction

Maximum efficiency in the generation and distribution of electric power can be obtained only when the power factor is maintained at a high value. Low power factor is the indirect cause of loss in the transmission and distribution system since the current in the conductors must be increased to maintain the same output. Increased current in the conductors may mean overheating, higher resistance and greater voltage drop which will again tend to increase the current.

Methods for increasing the value of the power factor have improved greatly during recent years, particularly the introduction of the capacitor or static condenser. Ten years ago, the only method of correcting power factor available to the industrial plant operator was that of installing a synchronous condenser at some point near the center of the heaviest load, or of replacing certain of his induction motors by synchronous motors. While the synchronous condenser is an excellent device for correcting power factor, it is expensive for small loads and requires a certain amount of upkeep and attention. Synchronous motors, on the other hand, cannot always be substituted for induction motors; therefore the small plant operator of 10 yr. ago had little alternative but either to accept low power factor or install a synchronous condenser.

Today, due to the successful development of the capacitor, not only is the power factor of the system easily controlled but the power factor of each piece of equipment if desired. Capacitors provide a very economical and desirable means of improving low power factor, because of their extremely high efficiency, low cost of installation and maintenance and because they require practically no attention.

To determine the proper application of capacitors,

a survey of all conditions affecting the installation should be made. Where a number of motors are involved, the capacitors in general, can be applied at three points on the distribution system as shown in Fig. 1. They may be connected directly at the motor terminals as at A; at the bus as at B or on the primary feeder C.

The greatest benefit can be derived from capacitors connected directly on the motor terminals; however, a large capacitor equipment applied at the bus may be entirely adequate electrically and prove more economical installation.

Capacitors are nothing more than paper dielectric condensers. The usual individual unit consists of one or more flat rolls of paper and aluminum foil clamped together and enclosed under oil in a sheet metal case. Each roll has two sheets of foil separated by thin laminations of paper. The terminals are brought out of the case through oil tight bushings.

Control Devices

Many new control devices are available today that were not in existence 10 yr. ago. Not only have a variety of new automatic circuit breakers and relays been developed for the control of individual pieces of electrical equipment, but new regulating devices for the electric power system as a whole have been designed. In connection with the matter of power factor correction, for instance, power factor control is becoming an increasingly important factor and regulators have been developed for just that purpose.

The simplest case of power factor regulation is that in which the excitation of a large synchronous motor is held at a favorable power factor in the machine leads. Provided the regulator transformers can be located in the bus structure so as to measure the entire mill load, the regulator will over-excite the synchronous motor so as to supply leading corrective kv-a. to improve the overall mill load power factor. If sufficient capacity is available, a plant purchasing power can be made to carry all its own reactive load or even supply leading kv-a. to the power system. A power factor regulator is a better application than an over-compensated voltage regulator, especially where system power factor voltages vary considerably during the day.

Power factor regulators are available which will maintain the power factor of the system approximately constant by varying the excitation of the synchronous machine under control until the line or machine power factor is changed as desired. Indeed the power factor control may be incorporated in the same regulator as the vibrating or rheostatic type voltage regulator. On the vibrating voltage regulator, the power factor control coil replaces the main control coil while on the rheostatic regulator it replaces the a.c. coil.

There are many industrial plants that purchase power on a kilowatt or horsepower basis rather than on a kilowatt-hour basis. It is naturally desirable to utilize this power up to the limit as closely as possible without exceeding the demand beyond which a penalty rate applies. With a fluctuating factory or mill load, hand control requires careful operation at an average purchased demand considerably below the contract limit, so that unexpected peak loads do not overrun the limit long enough to incur the higher rate for that billing period.

In such cases, the plant prime movers can usually be placed in control of load regulators that (1) automatically maintain proportional load division among machines; (2) hold the purchased power close to the contract limit by loading the plant generators with the remainder of the load including peaks. The steadier the load the closer the contract limit may be approached with safety and in any case this will be much nearer than with hand control. If desirable, another element can be employed, first to load the plant generators in this manner to their limit and then permit any further load to be carried by purchased power.

Such an arrangement may be made the basis of one lower rate applying to the base block of purchased power, with the higher rate applying only to the excess demand.

With any of these load regulator arrangements, a power factor regulator can be applied to throw part or all of the wattless load to the mill generators with a current limit element to protect the generators when necessary.

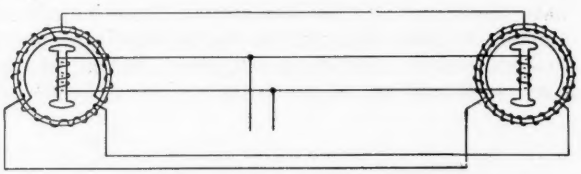
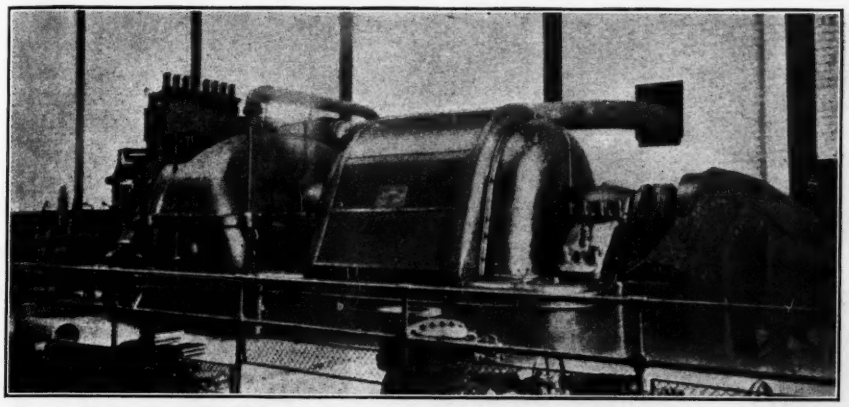


FIG. 2. THE PRINCIPLE OF THE SELSYN SYSTEM

One of the most interesting of control devices developed in recent years and one that has proved most useful in a variety of applications is the Selsyn system. Such systems are used for the transmission of small angular motions to distant points, in other words, it is a system for use in effecting remote control of equipment or remote indications. The simplest Selsyn system is shown in Fig. 2. It consists of two Selsyn motors connected by a transmission system. The Selsyn motor is mechanically a miniature bipolar rotating field, three phase alternator. In the circuit, the two rotors are excited from a common service. When one of the rotors is moved, mechanically, the other rotor in the corresponding motor also moves a similar amount.

Selsyn equipments are useful in indicating the position of generator rheostats, waterwheel governors, steam turbine governors, controller, hoists, etc.; they can be used for signalling between the switchboard and generator room or for the remote control of waterwheel governors, variable speed motors, gates or valves or of lights. They are also used for automatic control of the system frequency and in synchronizing of incoming generators.

In considering this question of control, it must be understood that here we have endeavored only to indicate some of the more recent developments. More than to describe any single type or to indicate its application, it has been our purpose here to acquaint the reader with the trend of progress, i.e. that almost everything that formerly was done by hand is now being accomplished automatically. The application of these automatic devices naturally requires careful consideration. It is not always economical or even desirable to employ automatic operation, but where its use can be justified, automatic operation nearly always is superior to manual operation.



TEN YEARS' PROGRESS

Joliet 1918

Fundamental Changes During a Decade As Shown by a Number of Plants, Outlined in an Interview with Wm. S. Monroe*

MR. MONROE was asked if he would review briefly his experience in Power Station design during the last ten years which have seen such remarkable development in the electric power industry.

"At the close of the World War," he said, "the best and largest electric power stations in this country were operating at about 250 lb. pressure and with steam temperatures about 600 deg. F. The largest generating units were of 30,000-kw. capacity and boilers delivered not over 75,000 to 80,000 lb. of steam per hour. During the War, the Joliet station had been built in the Chicago District with two turbine units of 12,500-kw. capacity operating at 300 lb. steam pressure and 625 deg. temperature. These were the highest steam conditions at that time, the Joliet plant being looked upon somewhat as an experiment.

Calumet Station

"Immediately after the War, the Calumet station was built in Chicago, the first unit (30,000 kw.) being put into operation in 1921. The station was afterward extended to contain six units of 30,000 and 35,000 kw. capacity operating at 300 lb. and 650 deg. F. Boilers had a maximum steaming capacity of 150,000 lb. an hour and were equipped with economizers, with small air heaters and also with both forced and induced draft fans. The boilers of the first two units had two chain grates under each boiler but, in the later boilers, large single grates 24 ft. in width were used. Soon after this station went into operation, it showed an efficiency of about 17,500 B.t.u. per kw-hr., which was about 10 per cent better than any of the stations previously built."

Development at Crawford Ave.

In reply to a question as to features in which Crawford Ave. station differed from Calumet, Mr. Monroe said:

"Designs were made for the Crawford Avenue station in Chicago, and at the same time for the Philo and Twin Branch stations of the American Gas and Electric Co. while the last section of the Calumet station was being built. In these stations we attempted some radical advances in station efficiency. The four factors which were to contribute to this improvement were: First, increasing the initial steam pressure at the turbine to 550 lb. pressure; second, increasing the temperature to 725 deg. F.; third, the use of progressive feedwater heating by steam extraction; fourth, the use of interstage reheating.

"Turbines in the Crawford Ave. station were all compound, the first units being 50,000 and 60,000 kw. capacity. The compound turbines were used mainly because at that time, the generator designers were unwilling to build generators of more than 30,000 or 35,000 kw. capacity. Crawford Avenue was developed to six units; the last two were 90,000 and 100,000 kw. capacity, all units being compound. On the last units the boilers at Crawford had a capacity of about 175,000 lb. of steam an hour. Chain grate stokers were used throughout this station, the largest having an area of 420 sq. ft.; also economizers and air heaters were used, the air temperature to the grates on the last boilers being about 275 deg.

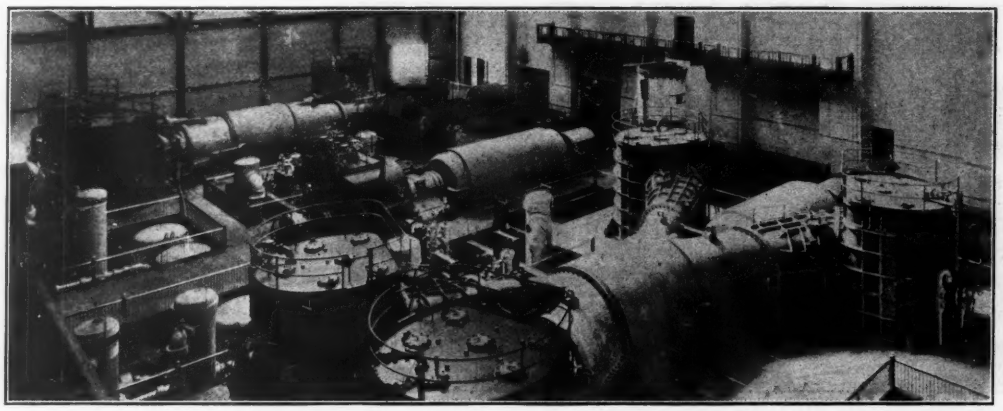
"When the Crawford Avenue station was laid out, it was expected to show an efficiency of 15,000 B.t.u. per kw-hr. on Central Illinois coal, running 10,000 B.t.u. per lb., containing about 14 per cent ash and 14 per cent moisture. After the station got into operation, some difficulty was encountered with corrosion which resulted from the low gas temperature and the high sulphur content of the coal. This led to some changes in the economizers and air heaters. After these were made, the station showed an efficiency somewhat better than 15,000 B.t.u. on low grade Illinois coal."

Pulverized Coal Adopted

Asked if he would explain the development which led to the use of pulverized coal in the State Line and Powerton stations, Mr. Monroe replied:

"The first unit at Crawford Avenue was put in operation in 1924, the last one, No. 6, in '28. During that period, the use of pulverized coal was being developed but we did not tackle it in the Chicago District because of the many difficulties that are to be encountered with pulverized coal operation when using a low grade coal with high ash and moisture content and a

*President, Sargent & Lundy, Engineers, Chicago, Ill.



State Line 1929

high percentage of sulphur, which are not encountered in pulverizing high-grade Eastern coals.

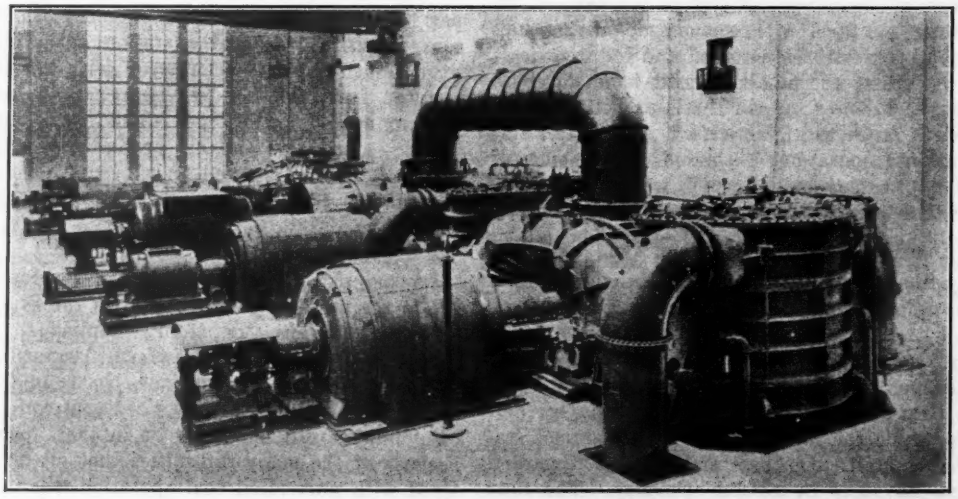
"In 1925 and '26 the Columbia Power station was built near Cincinnati with 40,000 kw., tandem-compound units operating at 600 lb. pressure, 730 deg. F. temperature, reheating at 110 lb. to 725 deg. and with steam-extraction feed heating. The coal used was from West Virginia, of about 14,000 B.t.u. per lb., and the station was built for pulverized coal using the central bin system with a pulverizing plant separated from the boiler room proper. This station was the largest pulverized coal installation of its time and for some years held the world's record for station efficiency, operating for months at a time at 12,500 B.t.u. per kw-hr. Later, new high-pressure turbines with generators were added, making the units cross compound. Some changes were also made in the furnaces by the addition of water cooling on some of the walls. These changes considerably increased the capacity of the station but somewhat reduced its efficiency.

"In 1925 we began experimenting with pulverized coal for the Chicago District and two boilers were installed at the Calumet station with water-lined furnaces equipped to burn pulverized coal. One of these was operated on the bin system and the other on the unit-mill-system. As a result of these experiments, it was decided to use pulverized coal on the unit-mill system in both the State Line and Powerton stations which were laid out in 1926 and went into operation in 1928. The main advantage in using pulverized coal in these stations was that we could use much larger boiler units than would be practical with chain grate stokers. In the first sketches for State Line, the 200,000-kw. unit was laid out with twelve boilers similar to the last ones at Crawford but, when we decided to use pulverized coal, we put in six boilers. This materially reduced the size of the building and effected other changes which reduced the unit cost of the plant."

State Line and Powerton Efficiency

Mr. Monroe was asked about the efficiency of the State Line and Powerton stations:

"Both the State Line and Powerton stations operate at about 625 lb. pressure and 740 deg. initial temperature. Powerton has boiler reheat while State Line has reheat by means of live steam. Both these stations are operating under 13,000 B.t.u. per kw-hr. Powerton has a six months' record of 12,610 B.t.u. per kw-hr., which is better than that of Columbia Power when proper allowance is made for the difference in the coal. The



Crawford 1925

first two units at Powerton were 50,000 kw., the third unit, which was put in operation last year, is 100,000 kw. and the fourth unit is now being installed. All these units are tandem-compound. The steam pressure is the same on all units but the temperature is somewhat higher on the last two."

Why 1200 Pounds

To the request that he tell why 1200 lb. pressure was used on the 125,000-kw. and the 150,000-kw. tandem-compound units which are now on order for State Line, Mr. Monroe replied:

"During the past 10 yr. three schools of power station engineers seem to have grown up, one advocating steam pressures not to exceed 400 lb., the second using pressures of 600 and 650 lb. and the third about 1200 lb. I do not want to go into all the arguments for these different types of stations. All of the stations designed and built by my office in the last few years operate at about 600 lb. pressure. Whether a station should use 600 or 1200 lb. requires careful study of the balance between the increase in fixed charges due to the higher pressure and the saving in fuel that it will accomplish. In every case that we have studied, the balance is very close and any station built for 1200 lb. pressure should be expected to operate at a high capacity factor, otherwise the higher fixed charges will not be offset by the saving in fuel.

"Deepwater station, near Wilmington, Delaware, which was put into operation about 2 yr. ago is, I believe, the largest 1200-lb. station in the world. My office served as Advisory Engineers representing one of the three companies that combined to build this station. All of the questions involved in the various operating problems in connection with this station were thoroughly discussed by a committee of engineers, one of the most important being the matter of steam pressure. The location of the station and the loads available indicated that it should be operated at a high capacity factor, which has been confirmed by the fact that for some months past it has operated at a monthly capacity factor of over 90 per cent.

"When we were building Crawford Avenue and Philo, we made a study of the higher pressures and worked out with the engineers of a leading boiler company a design for a boiler to operate at 1200 lb. pressure. This boiler was ordered for installation at the Calumet station with the idea of also installing a high-pressure turbine to make a trial installation for 1200 lb. pressure. Before that boiler was put into the factory, however, the order was cancelled because for many reasons we did not feel ready to go into a 1200-lb. development at this time. Immediately following, however, the Boston Edison Co. went ahead with a 1200-lb. installation.

"Since that time, the question of the higher pressure has been carefully analyzed for every major station we have built. At first the cost of a 1200-lb. installation was considerably higher than that of a 600-lb. plant. But the development of the higher pressure has greatly reduced the difference in cost, especially for large units of 100,000 kw. or more. Turbines of that size can now be built for 1200 lb. pressure at a cost not in excess of that for 600 lb. The pressure parts of the boilers cost more but for the high-pressure piping, although of course it has to be much heavier for 1200 lb., much smaller diameter can be used. Further, the saving in fuel due to the higher pressure and to the better reheat conditions that can be effected is very marked on these large units. Then, too, it is expected that the new units at State Line will be run as base load units for the Chicago District including northern Indiana."

Temperature Increase

The probability of increase in temperatures was next brought up and Mr. Monroe said:

"Increase in initial temperatures seems to have had an influence as great or greater than increase in pressure on reduction of heat consumption per kilowatt-hour. Increase in initial temperature rests largely on development of better materials and there is good prospect that 900 or even 1000 deg. may be practical before long. Initial steam temperature in that range will make it practical to do without reheating, which will tend to simplify the plant design as well as operation."

Future Improvement

In reply to the question, "To what factors can we turn for further improvement in economy?" Mr. Monroe replied:

"Further reduction in heat consumption per kilowatt-hour seems likely to involve such added first cost and complication as to lessen its probable economic value.

"Inasmuch as fixed charges per unit of output in most large stations are equal to or greater than operating costs, simplification of plant to reduce overhead seems the most important line of development. This will lead to the use of very large turbine units, having one boiler and one set of auxiliaries and probably without reheat but with full automatic control. Such a simplified plant should cost less per kilowatt capacity and have a long life, thus reducing the yearly percentage charge for amortization.

"In the future, as in the past, each power station will be a separate study involving consideration of all the varying conditions as to location, kind and quality of fuel, size of units and character of load."

Bobrukoffsche Stalin steam power station, which is being established in the Moscow coal mining area about 140 m. from Moscow, will comprise fourteen pulverized fuel fired boilers each with a heating surface of 26,910 sq. ft. and a normal steam production capacity of 340,000 lb. an hour at a pressure of 476 lb. per sq. in. The turbine room is being constructed so as to accommodate eventually eight two-stage turbines and generators, manufactured in Soviet Russia, each of a capacity of 50,000 kv-a. at a power factor of 0.9 when running at 1500 r.p.m. and generating power at 10,500 v. It is estimated that the station will require 10,000 t. of coal per day, for the transport of which special 50—60-t. automatically-discharging railway trucks are being built. About 2000 t. of ash and cinders a day will have to be dealt with and for its removal special hydraulic equipment is being installed.

Across-the-line motors give 100 per cent greater starting torque than standard motors with starters to reduce voltage to 65 per cent of line value as is necessary in larger sizes to meet N.E.L.A. requirements.

Steam Cycle Is Foundation of the Power Plant

CHARTS AID IN THE FUNDAMENTAL STUDY OF THE HEAT CYCLES AND SHOW EFFECTS OF TEMPERATUURE, PRESSURE AND CYCLE CHANGES

UNDERLYING all power plant developments are a few fundamental steam cycles which form a solid foundation or substructure for the industry. These cycles are not numerous and the practical ones, numbering but five, are given in the accompanying table. All of these cycles have been known and discussed theoretically for many years but it is only within the past decade that the last three have been practically applied.

Prior to 1920 the Rankine cycle represented by I and II in the table was used almost exclusively although there were a few extraction turbine installations supplying process steam. In addition, with some of the larger multi-cylinder reciprocating engines, receivers were bled for feedwater heating and a few had steam reheaters between cylinders but for all practical purposes, the dividing lines in the table can be considered as correct. Cycles above the line were in use prior to 1920, those below the line were developed subsequent to 1920.

I. Straight noncondensing
II. Straight condensing
III. Extraction
A) For industrial process
B) For feedwater heating
IV. Reheat-extraction
V. Binary-vapor

All of these are now in practical use and engineers are more or less familiar with the arrangement of the major equipment required with each one. Diagrammatic flow diagrams of the five are shown at the left of the drawing on the following page. In order to take advantage of increased pressures, temperatures, vacuums, extraction and possibly reheat it is advisable to know what heat economy changes can be expected.

This can be done in two ways: first by using blindly certain curves that have been drawn for specific conditions, which may or may not approximate those in question; second by learning the few fundamental relations upon which the calculations are based.

First and simplest is Cycle I, a straight, non-condensing Rankine cycle with a boiler and noncondensing engine exhausting, at atmospheric pressure, to a heating system. Exhausting to atmosphere would give the same condition. This cycle can be represented as a conventional indicator card on Pressure-Volume or PV axis as shown by the second vertical column. Beginning at A the boiler feed pump picks the condensate return up from the hot well and pumps it into the boiler B, where it is turned into steam along BC. This steam is then expanded in the engine cylinder (or turbine) along the line CD and exhausted to the radiators along DA. From the radiators it flows back to the hot well and the cycle is repeated. If a superheater is added the cycle is ABC′D′A, that is, on the PV diagram the superheat shows up only as an increase in volume.

As on an indicator card, the area of the card, representing the product of pressure and volume, is the work done in foot-pounds. For some purposes this diagram is not entirely adequate and the temperature-entropy chart as shown by vertical Cols. 3 and 4, is preferable. On these charts the area, the product of absolute temperature times change in entropy, is the work done in B.t.u. and as 1 ft. lb. equals 778 B.t.u., areas of the two diagrams are mutually interchangeable.

The diagram itself is extremely simple and easily drawn. Data for plotting the line XYZ is given in the steam tables; XY is the liquid line, YZ is the vapor line. Point Y at 706 deg. F. is the critical point where the densities of water and steam are equal. Area under the dome represents latent heat, to the left heat of the liquid area, to the right of superheated vapor.

Feedwater at A is pumped to the boiler and heated to saturation temperature along the line AB. Latent heat is added along the horizontal line BC at constant temperature and the steam is expanded in the prime mover vertically along CD and exhausted at constant temperature along line DA after which the cycle is repeated. Actual expansion in the prime mover is not vertical but slopes to the right as explained later.

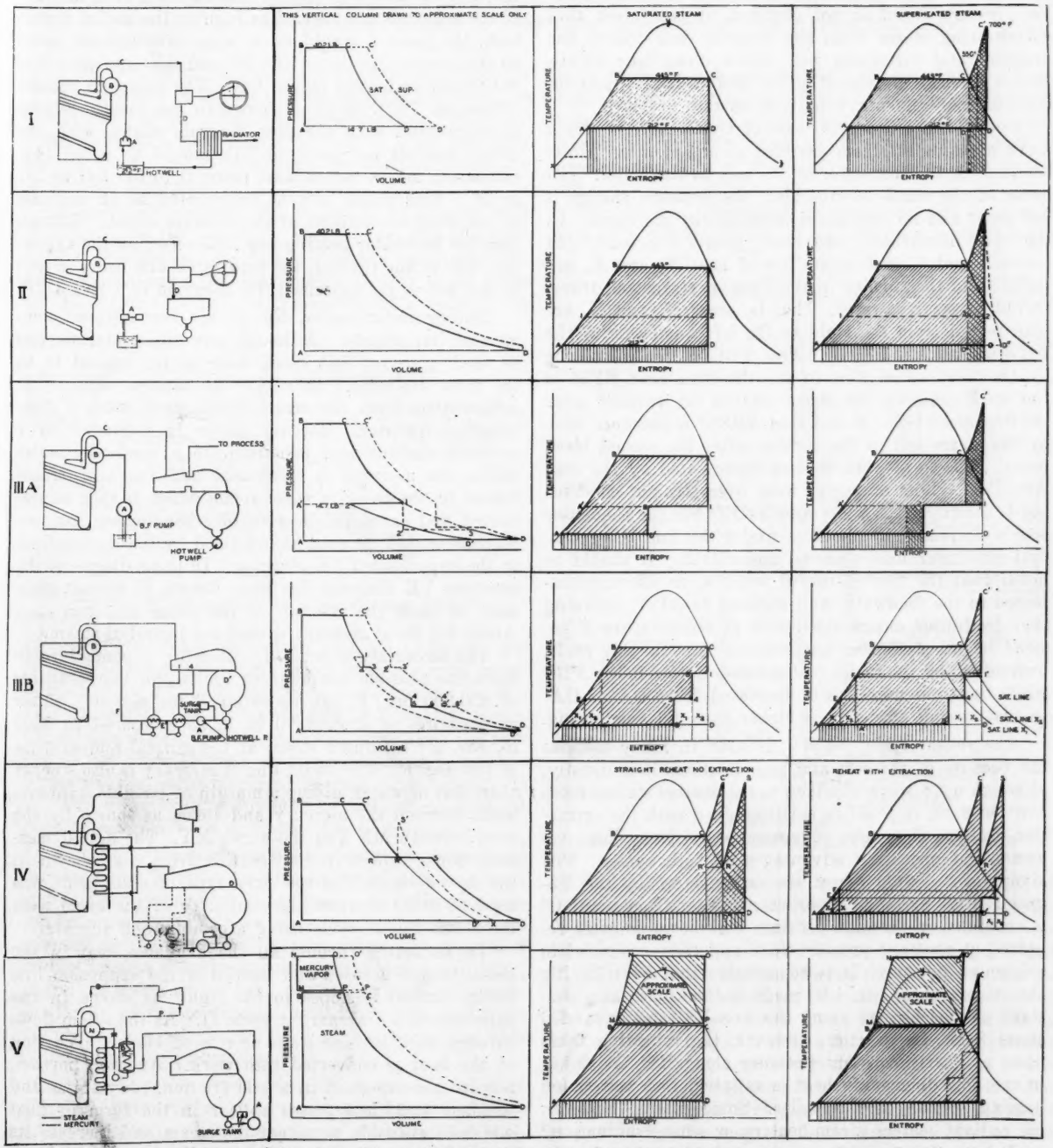
In this diagram the area under the line ABC represents the work or heat put into 1 lb. of water by the boiler and the area under the line DA represents the heat exhausted by the engine and sent to the radiators. This area below DA should extend down to zero degrees absolute but has been cut off at zero degrees Fahrenheit to save space. The heat represented by this area can be calculated from the equation $H = T(E_D - E_A)$ where H is the heat in B.t.u., T is the absolute temperature in deg. F. and E is the entropy at the respective points. From the diagram, $T = 460 + 212 = 672$; $E_D = 1.4839$ and $E_A = 0.3119$ so that $H = 672(1.4839 - 0.3119) = 787.6$ B.t.u. From the steam table the heat in the water at A is given as 180 B.t.u. and the heat in the steam at C as 1204.1 so that 1204.1 — 180 or 1124.1 B.t.u. are added in the boiler. As shown above 787.6 B.t.u. are exhausted to the radiators so that 1124.1 — 787.6 or 236.5 B.t.u. are converted into mechanical work. This value of 236.5 B.t.u. is the area ABCD. The area ABCD in B.t.u. is also given directly from a Mollier chart.[1]

Superheated steam changes the appearance of the PV diagram little because superheating takes place at constant pressure. On the TE diagram the change is very noticeable, the horizontal superheat line CC′ on the PV diagram becomes a steeple on the TE chart as shown by the diagrams in the fourth vertical column. The effect of the superheat is at once apparent. The available heat converted to work is increased by the double crosshatched area CC′DD′. This is not all clear gain, however, because the exhaust losses are also increased by the double hatched area under the line DD′.

In the second horizontal line, Cycle II, straight condensing, is shown. Calculations are the same as before,

[1]See Power Plant Engineering Turbine Performance from the Mollier Diagram, p. 1095, Nov. 15, 1931.

these two cycles being the same except for the change in back pressure. The area ABCD is considerably increased in Cycle II and as Cycle I and II are drawn to the same scale, the area A12D under the dotted line 1-2 represents the gain due to lowering the back pressure from atmosphere to a vacuum of 2 in. abs. The loss to exhaust is of course decreased by a like amount.



FIVE PRACTICAL CYCLES REPRESENTED BY FLOW DIAGRAMS, PRESSURE-VOLUME AND TEMPERATURE-ENTROPY CHARTS TO SHOW THE EFFECT OF PRESSURE, TEMPERATURE AND VACUUM CHANGES

Cycle IIIA is widely used in industrial plants usually with turbines although engines have been used for bleeding process steam.[2] This cycle is in reality a combination of Cycle I and II, with one prime mover serving the dual purpose of a back pressure and condensing machine. To make this clear, the turbine in the flow diagram is represented as a tandem compound unit. This would be the same for a tandem or a simple engine, one end condensing, the other non-condensing.

Steam to the turbine at C is expanded in the high-pressure cylinder to 1 and then exhausted, part going to process and part expanded in the low-pressure cylinder to condenser pressure. At point 1, one of two things may happen. The low-pressure cutoff (or in a turbine the grid valve) may be shortened to keep a constant receiver pressure, thus reducing the total vol-

[2]See Power Plant Engineering Steam Engines for Industrial Service, p. 501, May 1, 1931.

ume of steam to the low-pressure cylinder along the line 1-2. Expansion then takes place along the line 2D′D (with a negative loop on an indicator card). It is evident that the area, or useful work of the card, is reduced by the area 12D′D but the condenser loss is reduced in the proportion of steam that is bled. If the low-pressure cutoff is not changed, it is evident that withdrawing steam from the receiver will reduce the pressure and expansion will follow along line 12′3D. Which method of regulation is used depends upon industrial requirements; usually a constant pressure.

Cycle IIIB is a special case of Cycle IIIA in which small amounts of steam are bled at one or more points for heating the feedwater on its way to the boiler. Because of the small amount bled, the pressure change is not great and no regulation is ordinarily provided. In the cycle illustrated, two bleed points are used. At points 1 and 4 small quantities of heat X_1 and X_2 are taken from the turbine in the form of steam and transferred to the feedwater. That is, areas X_1 and X_2 are transferred from the right to the left hand side of the TE diagram as indicated. Area FBC1 is the work done by the total steam flow to the throttle; area EF34 is the work done by the steam left in the turbine after the first bleed point X and area AESD′ is the work done by the steam left in the turbine after the second bleed point. The total work is then represented by the area ABC35D′. Loss of useful work over straight condensing is shown by the white area 14D′D but the condenser loss is decreased by the area under the line DD′. Actual condenser loss is shown under D′A. It should be noted that the loss of useful work is, in effect, transferred to the feedwater and appears as AFA′, meaning that feedwater enters the boiler at temperature F instead of at condenser temperature A. In this cycle, heat added by the boiler is decreased from ABC to FBC while the condenser loss is decreased from DA to DA′ so that overall efficiency is higher than for condensing.

The reheat cycle, No. IV, is used in many stations but because of the cost and complications it is usually, although not always, confined to the central station field. Furthermore, in practice it is combined with the extraction cycle so as to take advantage of efficiency improvements and operating advantages of both cycles. The layout of a simple reheat station is shown by the diagram. High-pressure superheated steam from point C′ is expanded in the high-pressure turbine to point R, reheated at constant pressure to S and then expanded to condenser pressure. It is conceivable that by pumping the steam, reheat could be made to take place as a constant volume change along the line RS′ and expanded along S′X. In practice, however, the reheating takes place at nearly constant pressure along RS. As shown in the flow diagram, reheat is supplied in a convection heating section of the boiler. Some plants, however, use radiant heaters, steam heaters, or some combination.[3]

Reheat almost presupposes superheat so that the saturated steam TE of the third vertical column has been changed in this cycle to show a straight reheat cycle without extraction as shown by the solid line bypassing the extraction heaters on the flow diagram. It is not likely that such a cycle would be used but it serves as a stepping stone to the reheat-extraction TE diagram in the fourth vertical column. If, for the sake of argument, a reheat cycle with saturated steam were considered it would, on either the PV or TE diagram, follow the expansion line CR′RD′ because reheat applied to wet steam would take place at constant temperature.

Increase in available work is shown on the straight reheat diagram as the double crosshatched area RSDD′. If the reheat is not carried as high as the initial superheat, the point S would lie at some intermediate point on the constant pressure line RS and the expansion line SD would be moved to the left. The complete reheat-extraction TE diagram is shown in the fourth column to correspond with the flow diagram shown with the dotted heaters in operation. It should be noted that extraction moves the exhaust point D to the left as far as D′. This should not be interpreted as an increase in the moisture content of the exhaust steam. Extraction for feedwater heating has little effect on the expansion line of the turbine, the saturation line being moved to the left as on superheat TE diagram of Cycle IIIB.

Binary vapor cycles, No. V, are becoming of commercial importance. Although any two materials can be used, mercury and steam have so far proved to be the most desirable. In effect, the binary vapor cycle differs little from the steam reheat cycle with a combination reheater. Mercury vapor is expanded in a mercury turbine and exhausted to a condenser-boiler where the mercury is condensed and the heat transferred to the water to make steam which is then superheated and expanded in a regular condensing turbine. Extraction can be used as indicated by the dotted lines in the superheated TE diagram. In these diagrams the mercury TE diagram has been drawn to approximate scale to show the relation of the steam and mercury. About 8½ lb. of mercury is used per pound of steam.

The advantage is twofold. Efficiency depends largely upon the possible temperature limits and temperatures of 850-900 deg. F. can be obtained for mercury vapor at pressures of around 70 lb. g. as compared to 3200 lb. abs. for saturated steam at the critical temperature of 706 deg. F. The liquid line of mercury is also steeper than that of water, giving a margin of possible improvement between the mercury and steam as shown by the area between MN and the curve MY. The actual mercury boiler differs in construction from that shown in the flow diagram but the same type of equipment was used in order to show the similarity of the cycle with the steam reheat cycle using a combination reheater.

In an actual turbine all the available heat in the steam cannot be used and instead of the expansion line being vertical it slopes to the right[4] as shown in the superheat TE diagram for cycle II. As the steam flows through each turbine stage or row of blades, a portion of the heat is converted into work. Another portion, however, is expended in nozzle friction, eddy losses and windage and these losses appear in the form of heat which is available to reheat the steam and increase its temperature. Thus heat is actually being added all during the expansion period. Furthermore, the condenser loss is increased by the area under the line DD″. Effects of pressure temperature, vacuum changes, prime mover efficiency and cycle changes are readily apparent on charts of this kind. The chart construction is simple and their application, for fundamental heat balance and steam cycle studies, is of inestimable value.

[3]See Power Plant Engineering Reheat, practice, operation and control, p. 697, July 1, 1931, and p. 840, Aug. 15, 1931.

[4]See Power Plant Engineering Turbine Expansion Lines of Actual Machines, p. 1141, Dec. 1, 1931.

The Heat Balance Tells Where the B.t.u.'s Go

CALCULATIONS EASILY MADE AND RESULTS IN EITHER TABULAR OR GRAPHIC FORM ARE OF GREAT VALUE IN PREDICTING EFFECT OF DIFFERENT EQUIPMENT ON THE STATION HEAT RATE

IN SPITE of its importance in plant operation, the heat balance is shunned by the average engineer as a complicated device difficult to understand and more difficult to make. As a matter of fact, it is an extremely simple device, either a diagram or tabulation showing where the heat goes.

It serves the purpose of a budget or an account book depending on the way it is used. From the manufacturers' guarantees, the designer makes up a heat balance which shows the distribution of heat to all parts of the system. This is in the nature of a budget; the

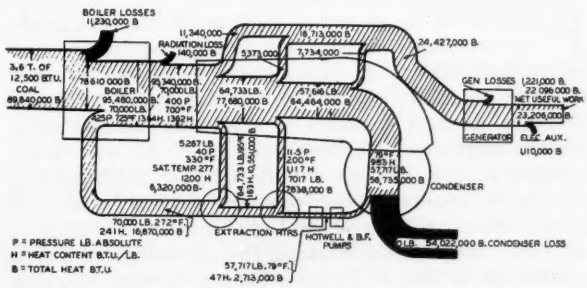


FIG. 1. HEAT BALANCE OF A SINGLE PLANT

income in the form of heat in coal, oil or gas is distributed to the various machines so as to leave the maximum possible available for the savings account, in this case the useful work in horsepower or kilowatts. Sometimes these guarantees are exceeded, sometimes the failure of one piece to come up to expectations will interfere with the performance of several other pieces. It is up to the operating engineer to make the actual expenditure agree with or exceed the budget.

Sometimes the engineer has no budget to work from in which case he must do a clever bit of detective work and find out where each B.t.u. goes. As ordinarily considered, the heat balance is a flexible device to be adapted to the individual requirements. It may be a tabulation or a diagram and the values may be in B.t.u., pounds of steam or per cent. It can be made extremely simple or very complicated depending upon the plant design, the engineer's need or the instruments available to obtain the necessary data.

In his detective work, Sherlock Holmes found that disguises were not only advantageous but were absolutely necessary. Instruments are the disguises with which the engineer works in the sometimes difficult detective work of tracking down the elusive B.t.u. so as to locate each one definitely on the heat balance. If you have not been keeping a heat balance, you will be surprised at the number of B.t.u., which should be doing active work, sneaking off into the sewer or into the river with the condensing water.

Again, the heat balance tells you just what each piece of equipment is doing and if you think a new machine would work in nicely, it is a simple matter to fit it in the heat balance and find out what effect it will have on the station as a whole. As used, the heat balance may be for some instantaneous, hourly, daily, weekly or monthly load conditions as explained in greater detail in a heat balance article later in the issue.

If the heat balance is so important and so simple, how is it made? Take as an example a plant using

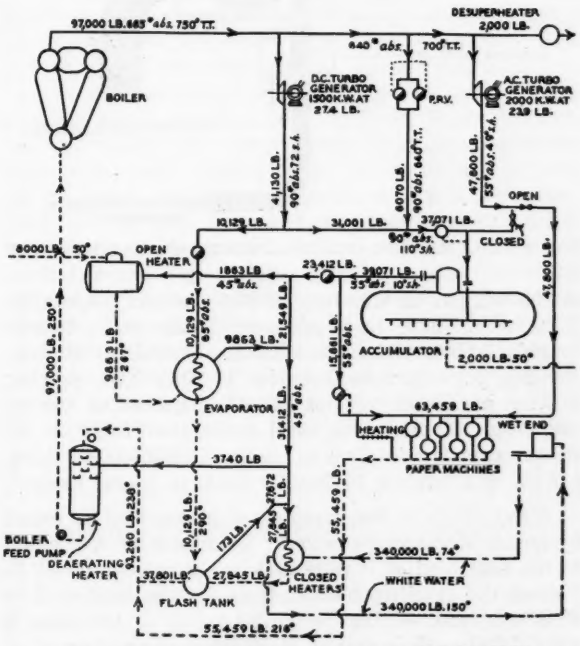


FIG. 2. AN INDUSTRIAL PLANT HEAT BALANCE

Cycle IIIB of the previous article with two stages of extraction. At a load of 70,000 lb. of steam per hour, 272 deg. F. feedwater and 12,500 B.t.u. coal, the boiler efficiency is 87.5 per cent. Boiler conditions are 425 lb., 725 deg. F. and steam reaches the turbine at 400 lb. 700 deg. F. At this steam flow, the expansion line of the turbine is as shown in Cycle II and the turbine is bled at two points, 47 and 11.5 lb. absolute, heat content 1200 and 1117 B.t.u. per lb. respectively. Steam to the condenser has a heat content of 983 B.t.u. per lb. Because of direct and large piping, pressure in the heaters is practically the same as in the turbine cylinder and the condensate is heated to within 5 deg. F. of the saturation temperature in the heaters. Both heaters are drained by a pump to the feedline ahead of the respective heaters. Generator efficiency is 95 per cent and the total auxiliary load, all motor driven, is 325 kw.

The total heat content of 70,000 lb. of steam is 95,480,000 B.t.u. of which 16,870,000 B.t.u. come in the feedwater, leaving 78,610,000 B.t.u. to be supplied by

[1] See Power Plant Engineering, Turbine Expansion Lines of Actual Machines, p. 1141, Dec. 1, 1931.

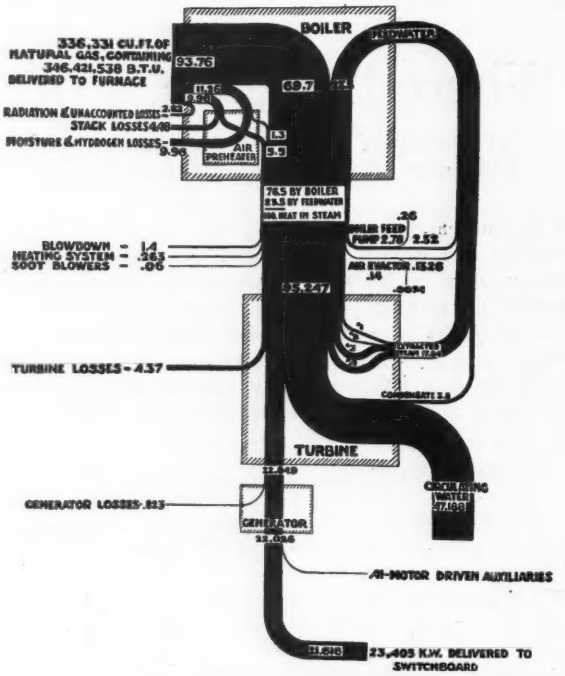


FIG. 3. A COMPLETE CENTRAL STATION HEAT BALANCE

the boiler. At an efficiency of 87.5 per cent, 89,840,000 B.t.u. would have to be supplied in the coal. This is roughly 3.60 t. Steam reaches the turbine at 400 lb., 700 deg. F. with a heat content of 1362 B.t.u. per lb.; 2 B.t.u. per lb. or total of 140,000 B.t.u. being lost by radiation. To the first bleed point the 70,000 lb. of steam expands and gives up 1362 — 1200 = 162 B.t.u. per lb. or a total of 11,340,000 B.t.u. in useful work.

Calculation of the amounts of steam bled is found by means of simple equations. Total heat at A is equal to the heat bled at B plus that in the condensate at C. Taking the quantity bled at B as X_1, the heat at A is $70,000 \times 241 = 16,870,000$ B.t.u.; at C the heat is $163(70,000 - X_1)$ and at B $1200X_1$. This gives

$$16,870,000 = 1200X_1 + (70,000 - X_1)\,163$$
$$X_1 = 5267 \text{ lb.}$$

Steam flow between the first and second bleed points is then 70,000 — 5,270 = 64,733 lb. The heat drop is 1200 — 1117 = 83 B.t.u. per lb. At the second bleed point the heat at C is equal to that at D plus that at E or with X_2 equal to the amount bled,

$$64,730 \times 163 = 1117X_2 + (64,730 - X_2)\,47$$
$$X_2 = 7017 \text{ lb.}$$

This leaves 64,730 — 7015 = 57,716 lb. of steam for the condenser, the heat drop of this quantity being 1117 — 983 = 134 B.t.u. per lb. Adding the three increments of power developed gives 24,427,000 B.t.u. at the coupling. The generator efficiency is 95 per cent, leaving a gross of 23,206,000 B.t.u. delivered by the generator. Of this, about 325 kw. or 1,110,000 B.t.u. are used by the auxiliary motors, leaving a net of 22,096,000 B.t.u. This is a load of about 6470 kw. These calculations are all made by slide rule to the nearest 1000 B.t.u. and are shown graphically in Fig. 1. The chart is very simple; it can be made as detailed as conditions and data warrant.

This chart, Fig. 1, is made in heat flow in B.t.u. per hr. A somewhat similar heat balance of an industrial plant is shown in Fig. 2. This is the Waldorf Paper Co. Plant[2] and quantities are all given in pounds of steam per hour. Still another central station heat balance figured in per cent of heat flow to the turbine is shown by Fig. 3. This is Belle Isle Station[3] burning natural gas. Because of the large moisture and hydrogen loss the boiler efficiency with natural gas is low.

[2]See Power Plant Engineering, p. 734, July 1, 1930.
[3]See Power Plant Engineering, Dec. 15, 1930, issue, for data and flow diagram of this station.

Progress in Automatic and Centralized Control

Automatic Control of Boilers, Auxiliaries, Turbines Has Aided in Low Cost Operation

PROGRESS in control of equipment has been made on two lines: automatic control of equipment and centralized control of equipment. Automatic controls of 10 yr. ago were mostly regulators actuated by steam pressure, furnace pressure or other factors and these master regulators through auxiliary devices, made changes in fuel and air supply, damper positions and the like to maintain steam pressure. Use of larger and larger boiler units, however, together with rise of pressure and temperature, changed the operating conditions materially in 10 yr. To keep pace with these changes, combustion control equipment was constantly improved to secure greater reliability, flexibility and sensitiveness. Another important development was that of the quantitative type of control in which the control equipment automatically makes measurements and records of the various factors similar to those which guide the operator in manual control. Control systems are available that correlate these measurements and adjust fuel and air supply, draft, water level and feed, furnace pressure and the like. The result is more uniform water level, quicker and more accurate adjustment of auxiliary speeds and, in general, more stability and evenness in operation than the average boiler operator can secure unaided.

This leaves the operator more opportunity for watching the operation of his equipment and gives him a more general idea of the entire operation. Since most of the combustion control systems are designed for change to manual operation if desired, the system functions not to supplant the operator but to aid him and improve his work. By eliminating unskilled labor, fluctuations in operation and losses due to inaccuracy of observation, combustion control systems have demonstrated their ability to lower the cost of a pound of steam.

Automatic control of generating equipment has not been applied so widely as of combustion control equipment, nevertheless much progress has been made. In many hydroelectric plants especially, most of the control is completely automatic. Governor oil pressure, opening of gates, adjustment of movable blades of propeller turbines, putting on the line and synchronizing, shutting down for bearing failure or generator overheating are only a few of the items under automatic control. With steam turbines, however, except for spe-

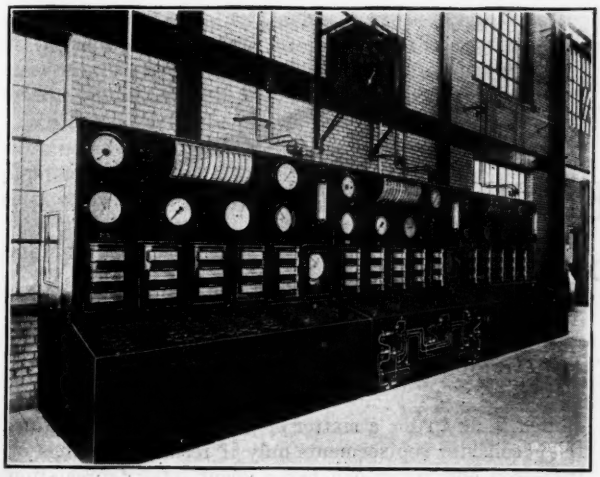


FIG. 1. WITH THIS MANUALLY OPERATED CONTROL BOARD, THE OPERATOR CAN PROVIDE PREMEASURED FUEL AND AIR AND CONTROL ALL AUXILIARIES FOR THREE BOILERS

cial conditions and safety devices, automatic controls are not used so much. Certain pumps and auxiliaries are automatically controlled.

As an example of recent automatic control practice, a boiler plant is now in operation entirely by automatic devices. The main fuel is gas from blast furnaces, with pulverized coal as auxiliary fuel. When the supply of gas is not sufficient to maintain steam pressure, pulverized coal burners are turned on and lighted automatically, fan speeds and dampers are adjusted, water levels regulated and all necessary operations performed by the control.

An interesting example of automatic turbine control for a 35,000-kw. unit for emergency standby service has been installed. The unit is kept warm and rolling at full speed at all times, the generator operating as a synchronous condenser. To put the unit on the line, throttle valve latches on main and house units are tripped opening the throttles rapidly. Through relays, this action speeds up the condenser circulating pump and induced draft fans, opens solenoid fuel valves on the boilers, opens main valves ahead of boiler feed regulators, starts forced draft fans. This control therefore, operates both turbine and boiler equipment and puts the station on the line in an extremely short time.

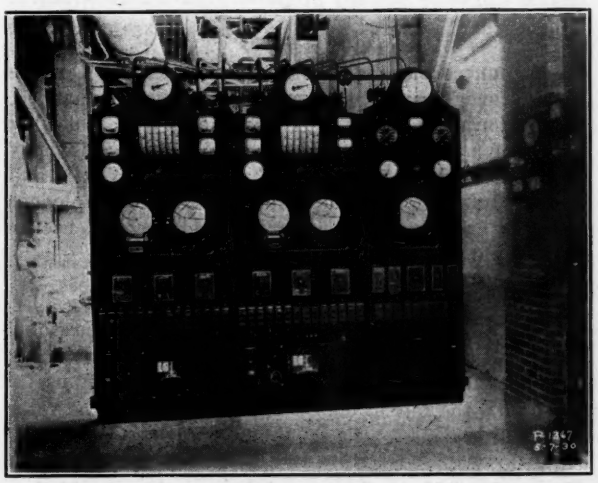


FIG. 2.. TYPICAL AUTOMATIC COMBUSTION CONTROL BOARD

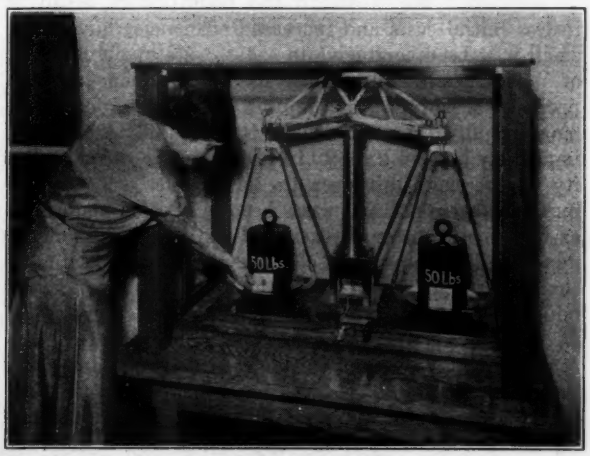
Automatic controls for maintaining total steam temperature include the use of desuperheaters controlled by thermostatic devices. For controlling reheat steam temperatures also, thermostatic controls can be provided. Motor-operated valves, automatic feedwater regulators and pump governors, temperature and load recorders, condenser leakage meters, smoke recorders are some of the automatic devices that assist the control systems in providing reliable and safe operation of power plants.

During the past few years there has been much interest in frequency and load control of power plants, details of which were given in the Feb. 15, 1931, issue of Power Plant Engineering.

Centralized control of power plants, a subject in which more and more interest is being exhibited, means the operation of the entire plant from one point. Such operation is principally manual, using meters and control devices recently developed. Special boiler meters pre-measuring pounds of coal and air, feedwater meters compensated for temperature variations, automatic scale indications transmitted by Selsyn motors, as used on the boiler control board shown in Fig. 1, have been used for this work. Development of miniature electrical meters has made possible a more compact design of control board for turbine generators and switching equipment. Motor-controlled valves can be remote operated from the control boards. As a result, where the economic conditions justify it, a centralized control room for operation of all equipment in a power plant is now entirely possible. A room of this type used at the new Bremo Station, has been reported to be extremely satisfactory.

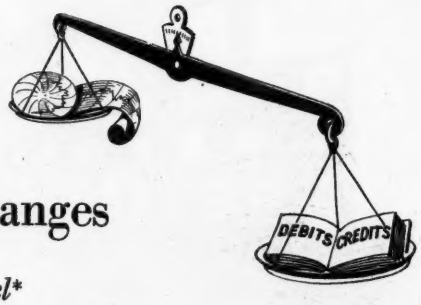
Three Pencil Marks Put Scale Off Balance

A SCALE IN THE METER laboratory of the General Electric Co. at Lynn, Mass., which will weigh up to 50 lb., is so accurate that three pencil marks, each 1½ in. long and weighing but 35 millionths of an ounce, will put it off balance. This is believed to be the most accurate heavy balance in the country.



WEIGHING THE EVIDENCE

Concerning Plant Changes



*By Ottomar H. Henschel**

REHABILITATION may be justified, or required, on account of (a) physical or (b) economic reasons, or both. Because, however, of continuous developments and improvements tending toward simplicity of operation, greater reliability, lower first costs and higher efficiencies the physical aspect, in the final analysis, may be eliminated leaving, except in unusual instances, only the economic factor for ultimate consideration.

Physical Aspects

It may be assumed that any unit possesses two lives. The first of these is its natural life, that depending upon the factors of obsolescence, inadequacy and uselessness, and the second, or operating life, which considers only the length of time required to retire it because of actual wearing out. The shorter of these is accepted as its true life.

Under ordinary conditions the natural life governs. But occasionally it does not. Due to negligence in operation, severity of service, the elements or other conditions, unanticipated or unforeseen, and perhaps not under control, repairs become frequent and extensive, maintenance costs mount and the operating life is unduly short. Obviously, then, replacement of the unit, or the whole plant resolves itself into a matter of time after which no alternative exists.

Economic Considerations

Improvements in design and manufacture resulting in less initial costs and increased efficiencies have in no small way been conducive to a high rate of obsolescence of power plant equipment. As a consequence and if properly accounted for, the unit is caused to depreciate more rapidly than otherwise. It is caused to carry an immediate burden directly in proportion to the superiority of the new unit over the older one. In fact this burden may in extreme cases become of such magnitude as to be equal to or in excess of the initial cost of the newer and perhaps more efficient piece of apparatus, so that failure to install the latter may result in actual added cost of operation. Obviously, then, purchase of the improved unit becomes not only desirable and economical but necessary, if depreciation and consequent fixed charges are to be maintained at a minimum.

Again and in the more usual case, the financial advantages accruing from the purchase and installation of the newer unit may cause a total depreciation of the existing machine within two, three or four years. Whether under such conditions replacement is warranted is, as a rule, a matter of policy. Not a few industrials consider replacements only if resulting savings or increased efficiencies can bring about total depreciation of the older unit within a period of two years or less. Others demand repayment within one year.

Not infrequently consideration is given to rehabilitation only after the unit or the whole plant has been entirely depreciated; that is, operating life has been made to exceed the natural life. Naturally, this may well be considered bad engineering although in some instances condoned by otherwise good accounting practice. The fallacy appears in the fact that, in determining costs under such conditions, practically all fixed charges are eliminated, resulting in erroneous conclusions.

Inadequacy

This is a condition met with when, because of growth of the industry, building or municipality served, demands upon the plant or system have occurred, resulting in periodic and frequent addition of small units, although existing equipment may not be obsolete. Generally, in cases of this kind and particularly under favorable load factors, increased economy will prove possible by replacement of the smaller boilers or electric generating sets with units of greater capacity. This is bound to be conducive to increased efficiencies, also to decrease of initial costs and of fixed and operating charges. The entire matter requires careful and thorough consideration from all angles, however, before steps be taken to carry out any proposed plan of rehabilitation.

Uselessness

A plant or unit thereof becomes useless when the service for which it was intended is no longer demanded. Water formerly taken from city mains and cooled by means of a cooling tower or spray pond for reuse may be supplanted by that secured from a deep well and delivered at little or no cost for handling. It is obvious that the cooling tower or spray pond becomes useless and should be depreciated immediately.

Determining Depreciation

Rate of depreciation varies, inversely proportional to the anticipated length of life of the equipment under consideration. If L be the anticipated length of useful life and R the rate of depreciation in per cent, the value of R will be:

$$R = 100 \div L$$

For a life of 25 yr. the rate of depreciation should then be $R = 100 \div 25 = 4$ per cent. In other words, each

*Consulting Engineer, Milwaukee, Wis.

year an amount equal to 4 per cent of the original value of the equipment should be put into the depreciation reserve until, at the end of 25 yr., the total depreciation reserve would be equal to the original cost.

In Table I are presented values representing accepted anticipated length of life of various pieces of power plant equipment, with corresponding commonly accepted rates of depreciation, Column B.

Virtually, however, the above method as commonly employed is incorrect. Development of the proper rate

TABLE I. LIFE AND DEPRECIATION FOR POWER EQUIPMENT

Unit	Assumed Life Years (A)	Yearly Depreciation, Per Cent Commonly Accepted (B)	Correctly Determined (C)
Boilers - fire tube	16	6.67	3.89
Boilers - water tube	20	5.00	2.71
Breechings and connections	10 to 25	4.00 to 10.00	7.59 to 1.82
Buildings - brick and concrete	50	2.00	0.35
Buildings - wooden	50	2.00	0.35
Cables - underground lead covered	25	4.00	1.82
Cables - aerial lead covered	16	6.67	3.89
Coal and ash handling equipment	20	5.00	2.71
Condensers	25	4.00	1.82
Conduits	50	2.00	0.35
Electrical auxiliaries	10	10.00	7.59
Engines - steam low speed	20	5.00	2.71
Engines - steam high speed	16	6.67	3.89
Engines - gas	16	6.67	3.89
Feed water heaters	30	3.33	1.26
Feeders - weatherproof insulation	16	6.67	3.89
Fencing - steel	20	5.00	2.71
Foundations	Life same as supported machinery		
Fuel oil handling equipment	25	4.00	1.82
Generators - modern	20	5.00	2.71
Generators - obsolete	16	6.67	3.87
Generators - steam turbo	10	10.00	7.59
Meters - electric switchboard	20	5.00	2.71
Meters - electric service	16	6.67	3.89
Piping and covering	25	4.00	1.82
Pumps - steam	20	5.00	2.71
Stack - brick	50	2.00	0.35
Stack - steel	10	10.00	7.59
Steel - structures	25	4.00	1.82
Stokers - fixed parts	20	5.00	2.71
Stokers - moving parts	5	20.00	17.74
Storage batteries	16	6.67	3.89
Switchboard and wiring	20	5.00	2.71
Telephones	10	10.00	7.59
Transformers - station service	16	6.67	3.89
Turbines - steam	20	5.00	2.71
Turbines - water	16	6.67	3.89

of depreciation to be employed is complicated, involves lengthy mathematical processes and would require no little time in the derivation of rates for various values of anticipated life of unit, or machine, and rate of interest. Such rates of depreciation are, however, given in Table II as presented by O. B. Goodman in his treatise on the subject of Financial Engineering. Referring to this table, with an anticipated life of 10 yr. and with an interest rate of 6 per cent, compounded, a depreciation rate of 7.587 per cent yearly should be used instead of 10 per cent.

Depreciation rates given in Column C, Table I, are based upon an interest rate of 6 per cent and for life and depreciation rates as presented in Table II.

Theoretical Consideration of the Whole

After an involved development, Gillette and Dana present the following fomula:

$$E + (C - S)\,F + rC = e + rs$$

in which

- E = Equated annual operating expenses (including taxes) during the entire life of the new plant.
- e = Equated annual operating expenses (including taxes) for old plant during its remaining life.
- C = First cost of the new plant.
- S = Salvage value of the new plant.
- s = Salvage value of old plant.
- F = Functional depreciation (that due to obsolescence, inadequacy, etc.) annuity rate for the new plant.
- r = Annual charge rate, including interest, risk, insurance and proprietary supervision not included in F, E, and e.

When the left-hand member of the formula becomes less than that on the right-hand side, the old plant should be retired in favor of the new.

Plant Improvements

Frequently, rehabilitation is limited to the addition of equipment only, without regard to existing major units. Improvement may be sought by the possible installation of stokers, economizers, water softening apparatus, the changing over from non-condensing to condensing operation, coal and ash handling equipment, instruments such as CO_2 recorders, draft gages, steam flow meters, and the like.

In the case of stoker installations, coal cost savings due to increased evaporation, greater capacity and the possible use of a cheaper grade of fuel must at all times be debited with accruing fixed and operating charges, due to the adoption of the unit. Whether the net savings warrant the required capital expenditure then resolves itself into a question of personal opinion or policy.

Again, water for a manufacturing plant was available either from a local deep well or from city mains. That from the former source, however, required treatment while the other was purchasable only at a comparatively high rate of charge. Consideration was given to the possible purchase of softening equipment but after due study of the problem it became apparent that because of excessive operation costs no financial advantage would accrue from the use of treated well water.

Instruments such as referred to are always desirable. With proper use under competent supervision, their purchase and installation as a rule proves profitable. In fact, because of their use, annual economies realized not infrequently outweigh their initial cost many fold.

TABLE II. DEPRECIATION RATES FOR VARIOUS LIFE AND COMPOUND INTEREST RATES. O. B. GOODMAN

Life	Interest Rate							
	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
1	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
2	49.261	49.020	48.780	48.544	48.309	48.077	47.847	47.619
3	32.353	32.036	31.722	31.410	31.106	30.804	30.505	30.211
4	23.902	23.563	23.203	22.859	22.523	22.192	21.867	21.547
5	18.836	18.471	18.099	17.739	17.389	17.046	16.701	16.380
6	15.460	15.082	14.703	14.336	13.980	13.632	13.292	12.961
7	13.051	12.665	12.305	11.913	11.555	11.207	10.869	10.541
8	11.244	10.856	10.473	10.104	9.747	9.402	9.068	8.744
9	9.843	9.452	9.070	8.702	7.879	8.008	7.680	7.364
10	8.724	8.331	7.951	7.587	7.236	6.903	6.582	6.278
11	7.808	7.417	7.039	6.679	6.335	6.007	5.695	5.398
12	7.046	6.657	6.283	5.928	5.590	5.269	4.965	4.676
13	6.405	6.016	5.646	5.296	4.965	4.652	4.357	4.078
14	5.853	5.468	5.103	4.759	4.434	4.130	3.844	3.575
15	5.376	4.995	4.634	4.296	3.979	3.683	3.406	3.147
16	4.961	4.583	4.229	3.895	3.586	3.298	3.030	2.782
18	4.271	3.900	3.555	3.236	2.941	2.670	2.421	2.193
20	3.722	3.358	3.024	2.718	2.439	2.185	1.955	1.746
25	2.743	2.401	2.095	1.823	1.581	1.368	1.181	1.017
30	2.102	1.783	1.505	1.265	1.059	0.883	0.734	0.608
35	1.654	1.358	1.107	0.897	0.723	0.580	0.464	0.369
40	1.328	1.052	0.828	0.646	0.501	0.386	0.296	0.226
50	0.887	0.655	0.478	0.347	0.246	0.174	0.123	0.108
60	0.613	0.420	0.283	0.188	0.123	0.080	0.051	0.033
75	0.367	0.223	0.132	0.077	0.044	0.025	0.014	0.008
100	0.165	0.081	0.038	0.017	0.008	0.004	0.002	0.001

One large lamp is more economical than a cluster of smaller ones. A 300-watt lamp gives 17.9 lumens per watt, while three 100-watt lamps give only 13.6 lumens per watt of energy expended.

For sweating water pipes, metal eaves troughs may be slung beneath the pipe and drained to some point where the water can be disposed of easily.

Comparison of Equipment Efficiencies

WHEN CONSIDERING the replacement of old equipment with new, one of the principal factors is the efficiency of operation; the question is what can be gained by making the change. To solve this problem,

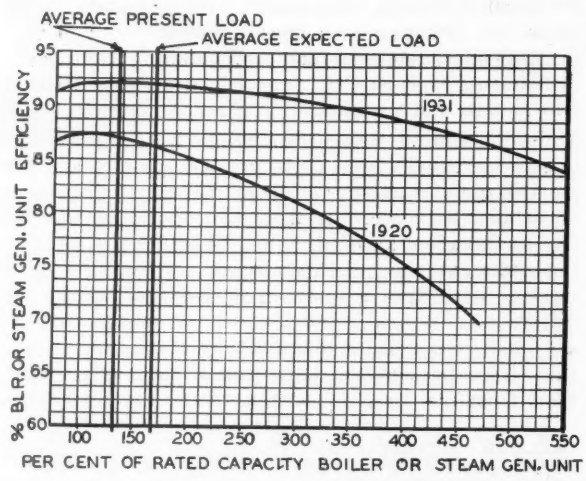


FIG. 1. CAPACITY-EFFICIENCY CURVES FOR STEAM GENERATING UNITS REPRESENTING HIGHEST EFFICIENCIES OBTAINABLE IN 1920 AND 1931

there is no better way than to compare present efficiencies with those of the new equipment as guaranteed by the manufacturers. The efficiency curves of the present and new equipment should be plotted on the same chart for the various loads which are likely to be encountered. The gain in efficiency can be expressed in percentage or in heat equivalent over a typical load period or in dollars and cents as may be desired and by this means direct comparisons can be made which will show the gain in economy by the change under consideration.

To illustrate the method, reference is made to the capacity-efficiency curves in Fig. 1 representing the best boiler practice commercially obtainable in 1920 and 1931. The present and expected load curves are illustrated in Fig. 2. Inspection of these curves would indicate that the best possible average efficiency of the 1920, 1000-hp. unit under present load conditions is about 87 per cent. For the expected future load, the efficiency would average about 86 per cent. Now considering a

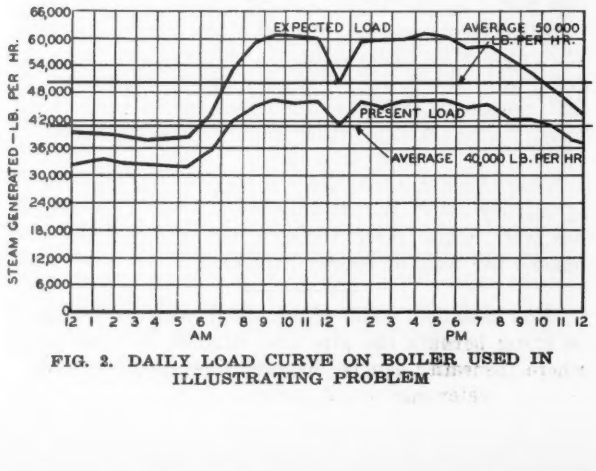


FIG. 2. DAILY LOAD CURVE ON BOILER USED IN ILLUSTRATING PROBLEM

new modern unit of the same rated capacity, the best possible efficiency under present load conditions should be in the neighborhood of 92 per cent and with the expected future load it should remain at about 92 per cent as the efficiency curve is relatively flat at the load represented by the load curve. The reduction in fuel required would be 92 — 87 = 5 per cent or with a 1000-hp. boiler plant the saving would be $38.50 per week or $2000 per year with coal at $2.00 per ton. For the expected future load, the savings due to the new equipment would be 6 per cent, or $2470 per year.

Similar efficiency comparisons should be made for each important unit in the plant where the plant survey has indicated the equipment to be obsolete or inadequate.

Heat Balance Studies

IN REALITY a heat balance is a budget with heat units as the medium of exchange instead of dollars. The object, of course, is to accomplish all the purposes for which the plant was built with as little waste of heat as possible. So in a study of a plant for rehabilitation possibilities, the various proposed hookups with their calculated heat balances at three or four different typical loads should be compared in detail. In many cases, such a study will suggest a hookup which is a combination of the best features of the original plans.

In the present discussion, case studies cannot be made, so rather explicit general directions for making a systematic comparison of proposed schemes will be given. With this in mind, the accompanying table has been prepared. The items in the left-hand column will have to be changed to conform with the heat balances being compared, the column headings, however, are quite complete and data under them should not be omitted without first considering effect on results.

In making up this table, it will be noted that the aim has been to list all equipment proposed in each hookup scheme which has to do with the transfer of energy or its conversion from one form to another. In this comparison, each load condition will suggest the use of a different combination of units in the plant, so it is well to consider each step as a unit. Thus, for each condition, all boilers in service will be considered as a unit and their combined results used in the comparative table.

Data for the columns headed "average per hr. for normal weekly load" are the heat balances for the plant calculated on the basis of the load curve and the program of the equipment in service. It may be found that the heat balances reported here indicate that the most desirable scheme is not the one that might be chosen for the average load on the plant. The method suggested is to study the load curve to determine the schedule of equipment to put into operation, calculate the heat balance for the average load over the period represented by each program of equipment, sum up the results for the load cycle of a week or month, as the load curve indicates, and take average hourly results for data.

Data for this table can be secured as a result of special tests run on equipment in the plant, from a study of the plant load curve and plant service requirements, and from guarantee figures furnished by manufacturers.

Plants that provide only power service usually base their load on the electric output but those that supply other services also, such as heat for buildings and

FORM FOR COMPARING HEAT BALANCES OF DIFFERENT PROPOSED SCHEMES UNDER DIFFERENT LOAD CONDITIONS

HEAT BALANCE ITEMS	EQUIVALENT B.T.U. PER HR.																											
	STAND-BY LOAD			ONE QUARTER LOAD			ONE HALF LOAD			THREE QUARTERS LOAD			FULL LOAD			AVERAGE PER HR. FOR NORMAL WEEKLY LOAD						HEAT BALANCE WITH PURCHASED POWER – AVERAGE PER HR FOR NORMAL WEEKLY LOAD					
																SUMMER			WINTER			SUMMER			WINTER		
	RECEIVED	CONVERTED OR RECLAIMED	LOST OR REJECTED	RECEIVED	CONVERTED OR RECLAIMED	LOST OR REJECTED	RECEIVED	CONVERTED OR RECLAIMED	LOST OR REJECTED	RECEIVED	CONVERTED OR RECLAIMED	LOST OR REJECTED	RECEIVED	CONVERTED OR RECLAIMED	LOST OR REJECTED	RECEIVED	CONVERTED OR RECLAIMED	LOST OR REJECTED	RECEIVED	CONVERTED OR RECLAIMED	LOST OR REJECTED	RECEIVED	CONVERTED OR RECLAIMED	LOST OR REJECTED	RECEIVED	CONVERTED OR RECLAIMED	LOST OR REJECTED
SCHEME (PRESENT) OVERALL																												
BOILERS																												
PRIME MOVERS																												
GENERATORS																												
PUMPS FOR SERVICE OUTSIDE																												
COMPRESSORS FOR SERVICE OUTSIDE																												
PROCESS STEAM																												
CONDENSERS																												
HEATERS																												
EVAPORATORS																												
ECONOMIZERS																												
AIR PREHEATERS																												
AUXILIARIES																												
ACCUMULATOR																												
SCHEME 2 OVERALL																												
BOILERS																												
PRIME MOVERS																												
ETC.																												
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SCHEME 3																												
BOILERS																												
PRIME MOVERS																												
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processes, compressed air, water, refrigeration and ventilation, will probably find it most convenient to base their load ratings on the capacity of the boiler plant from which all energy is secured. Many industrial plants of today have connection with utility power plants and in such cases other columns should be added for comparing the heat balances resulting when different proportions of steam and electric loads are used.

Economic Considerations

IN THE LAST analysis, the only justifiable reason for rehabilitating a plant is from an economic standpoint. It is only when unit costs can be reduced or reliability definitely improved by replacing or adding to the equipment in a plant that the engineer is justified in advocating the necessary expenditures. And this gain in economy must indicate a net return on the investment for improvements of 15 per cent or more.

Each plant, of course, is an individual problem and to arrive at the correct solution all the items entering into the cost of production should be listed separately for each of the schemes which the efficiency and heat balance studies indicate as worthy of further consideration. As an illustration of how the items may be listed, the accompanying form prepared for a steam generating plant is presented. When properly filled out from plant records and estimates for the proposed new equipment, unit costs can be calculated and the relative economic value of the different schemes compared. Unit costs should be calculated over a definite load cycle such as usually occurs weekly rather than monthly. Also, typical periods should be selected such as for summer and winter, as in some instances the unit costs vary widely and influence the choice of equipment or determine the program of operation.

When comparisons are made, it will usually be found that new machinery or construction that will reduce present unit costs or improve the quality of service must do so by increased efficiency of operation over that possible with the use of existing equipment. Increased efficiency of operation will reduce costs by saving in cost of one or all of the items of fuel, supplies, labor, repair and renewals, i.e., the variable charges that enter into unit costs. Some of the fixed charges may also be reduced by investments in new equipment. Thus it may be found that the amount set up for obsolescence and inadequacy may be reduced, due to advances in design which makes further improvement less likely in the future. Insurance may be reduced due to safer designs and the use of better materials. Taxes or rent would be reduced by reduced size per unit of capacity of the new equipment. Likewise interest on investment would result in a saving if the cost per unit of capacity of the new equipment were less than the old.

So varied are the needs of industry and so subject to influence by such diverse factors, especially in a new and growing community or a new industry, that calculations based on past demands for power are of doubtful value and the average designer of power plants is justified in providing machinery adequate only for the natural expected growth in the immediate future. By the time that the natural growth of the demand on the plant has exceeded its available output, more up-to-date and economical machinery will likely have been invented; additions to the power generating equipment naturally should be of the newer type, therefore, interest on money which has been tied up in unused machinery would be lost in any case and if such equipment became obsolete in the meantime the loss of a large portion of the capital investment would also be incurred.

Wise engineers, therefore, do not build too far into the future; they limit investments to needful equipment and as a rule the capacity of power plants will be found to be overtaxed and in need of additional capacity rather than the contrary.

ITEMS ENTERING UNIT COST CALCULATIONS

Costs of Production	Costs with Present or 1st Scheme	2nd Scheme	3rd Scheme	4th Scheme
Variable Charges				
Coal				
Water				
Oil, Waste, Supplies				
Labor				
Repairs				
Renewals				
Fixed Charges				
Obsolescence and Inadequacy				
Insurance				
Taxes or Rent				
Interest on Investment				
Management (overhead)				
Output or Plant Services	Amount Delivered			
Steam lb.				
Power kw.-hr.				
Water gal.				
Ice lb.				

Editorial Comment

The Modernistic Trend

Ten years is a short length of time, yet during the period from 1909 to 1930 the power industry expanded at an unbelievable rate. With some exceptions, plants built in 1920 are obsolete, and efficiency, as required by modern industry, demands that these obsolete plants be replaced. To assist us in pointing out advances in practice, we requested the co-operation of some 1000 manufacturers of equipment by asking the following direct question:

"What design and efficiency improvements has your company made in its products during the past decade that would warrant a client who installed a piece of your equipment in 1920-22, replacing it with your latest 1931 model? This replacement might be by new design of the same equipment, by new equipment intended to take the place of the old, or by rebuilding the old equipment to comply with your 1931 standards."

As might be expected, the replies ranged all the way from "We build first class equipment. It is much better than ever before. Everyone should have one," to "Since 1920 our efficiency on this size of equipment operating under the following conditions has improved 15 per cent." It is significant that those companies who are recognized leaders in the field, who take an active interest in the industry, were the ones that had the data to answer our question. Information obtained from these replies, for which assistance our appreciation and thanks are hereby extended, has been incorporated in certain sections of this issue. The list of coöperating companies cannot be given here for lack of space but will be found on page 56.

Evidence is sufficient to convince even a casual reader that a plant built 10 yr. ago is hopelessly out of date and the chances are that it is an actual liability to the industry it serves, if compared to modern plants being used by competitors.

This does not necessarily mean that the equipment installed in these plants is obsolete. A plant may be out of date, while most of the equipment in it may be in first class condition, requiring only some rearrangement and a few new key machines to bring it up to date. A boiler may be small and perhaps inefficient but the installation of a new stoker with perhaps a combination of air and water-cooled walls, economizer or air heater would double its capacity and bring the efficiency up to what it should be.

The purpose of this issue is not to prove that your present plant is worthless; rather it is to point out advances that have been made in certain lines so as to bring up in your mind the question, "Can my plant do better than it is doing?"

To answer this question, it will be necessary to take the plant unit by unit and consider such things as "Flue gas is being cooled to 300-350 deg. in some plants; what would I gain by cooling mine from 750 to 300?" and "Some plants are using bleed steam to heat feedwater to 400 deg. F.; what would I gain by putting in a high-pressure heater to use 125 lb. steam from the high-pressure process extraction line?"

Manufacturers are glad to quote prices on equipment necessary so that you can find out whether the savings would justify the investment. We have pointed out in detail the steps necessary in such a survey and check up on your plant and our sincerest wish for the coming year is that it will see you well on the way to a plant to which you can take a visitor and say with pride—"This is the best power plant possible for our conditions. I know because I've checked it piece by piece, made changes where necessary, after considering the recommendations of manufacturers, and compared its performance as a whole with other plants in this and other industries."

Elements of Progress

In almost all technical developments it will be observed that by some peculiar quirk of our engineering minds, we frequently begin these developments with the more complicated equipment and methods and work toward the simpler forms. This characteristic is common to both inventor and engineer; in the case of the latter it is probably due to economic causes, while in the case of the former it may be due to his use of the deductive rather than the inductive method of reasoning.

In other words, having once installed a certain method or apparatus for performing a given piece of work, the engineer must keep it running and producing even though in many cases he has thought of better methods or knows of better equipment for the same work. He must introduce his changes slowly, always maintaining service and always justifying his improvements on economic as well as on engineering grounds. Sometimes he must wait until his existing equipment must be entirely replaced before being able to demonstrate the desirability of the new idea or the new equipment.

The inventor often jumps at the first device or combination of elements that will give him the result he seeks and, only after he has an apparatus that gives him the result he seeks, does he attempt to find out whether or not he is attaining it by the simplest and most economical means.

Development from complexity to simplicity is by no means to be condemned. It must always be remembered that the human race demands first of all results from its technicians. Their function is to provide things that people can use, even though in the beginning the results are not always obtained in the simplest way, when regarded from the point of view of later development.

These two factors are nowhere better illustrated than in the December 15, 1931, and January 1, 1932, issues of Power Plant Engineering. In the December 15 issue, discussing development of equipment, the trend toward simplification of physical equipment is

clearly brought out. Not only are steam generating and power-generating equipment being simplified but also general plant layout and control are undergoing far-reaching changes. In the present issue, the influence of these great physical changes and of the economic factors involved in improving and simplifying power plants is discussed.

It is difficult to say whether the demands of the engineer or the response of the equipment manufacturer has been more important in bringing about these improvements. It will be seen that, while simplification of equipment from the earlier and more complex developments to the more simple and efficient forms constitutes technical progress, many economic factors must always be evaluated in connection with the technical analysis. Power plant engineers and manufacturers of equipment generally are studying these interlocking relationships with much care. The improvement in economy and simplicity of power plants and distribution systems that they have made during the past 10 yr., is evidenced by the data given in this issue.

Powered Houses

Notably during the existence of recent previous as well as the current business inferiority complexes, power use has made a remarkable showing in maintaining volume. In every case this has been, to a considerable extent, due to increased use of electricity for domestic purposes in homes, hotels, restaurants and office buildings for washing, refrigeration, ventilation and cooling, sweeping, operations pertaining to cooking and to a small but increasing extent for heating. Availability of these household conveniences has not only built up load in buildings already using current but has been an added incentive for wiring houses not supplied with electricity.

Not infrequently is now heard the comment that the rate of increase of power load is or soon will be growing less. That small industrial plants are now well taken over onto the utility supply systems. That, because of availability of higher pressures and small generating equipment which fits well into the heat balance of industrial plants, industries are giving careful attention to power as a low-cost byproduct from heating and process steam. That the trend is shaping toward greater use of individual and group plants for industrial power.

Time will show whether or not these comments are well founded but, in any case, there would seem to be a big opportunity for utilities in further cultivating the domestic-uses market for electric current.

On the basis as estimated that home lighting in some 20,000,000 homes is only from 20 to 30 per cent of standards now favored as good practice and that use of domestic appliances is probably not over 15 per cent of that profitable for human well being, not only is additional annual revenue of some $2,000,000,000 awaiting the tilling of this field but a market for electrical equipment appears of some $3,000,000,000.

Big figures, yes. Not realizable at once, but an end worthy of attainment. If that amount of power load and equipment market were in sight, there would be a grand rush to secure it. The domestic load is subject to no competition but it must be built up by education and encouragement. Steady, continuous effort should be able to establish the fully powered and electrically equipped house on the same basis of need as the present unquestioned requirements for full water supply and plumbing.

Hydraulic Research

Importance of model testing and laboratory investigation, in their relation to the continued vigorous growth of the hydraulic industry, cannot be overemphasized and should be considered as a major objective of interest and for stimulation by the A. S. M. E. Hydraulic Division for the coming year, according to the recent progress report of the division. Notable instances of the variety and value of such work are the pitting investigations at the Shawinigan Falls laboratory, the testing of model runners and draft tubes at the Holtwood laboratory, the investigations of most economical design of flumes, canals, spillways and other items at the Alden laboratory. The successful outcome of the 12-yr. fight for a national hydraulic laboratory, which is expected to be finished in 1932, leads hydraulic engineers to hope that this institution will prove of the highest assistance in the fundamental research work of the entire field.

This entire question of hydraulic research has a most direct bearing on the development of hydroelectric and steam power in this country. With hydraulic prime movers now in operation at efficiencies as high as 94 per cent, it might seem that there is small chance of improvement. Yet such results were not obtained 10 yr. ago and every hydraulic engineer knows that they are obtained now only because of the research work done by manufacturers and operating engineers. A little saving on a water passage here, a gain of half a per cent on a water wheel efficiency there, a new and more economical practice in operation somewhere else —all put together have mounted to a worthwhile gain. Each one in itself is often considered hair-splitting but when totaled the gains are important.

It is interesting to note that the present ratio between the total amount of hydroelectric developed power and the total amount of steam power developed is practically the same as it was 10 yr. ago. In fact, the N. E. L. A. data show that of the prime movers in the United States 17 per cent in 1920 were water power units and 20 per cent in 1930.

In view of the present fuel situation, however, and the influence on it of the oil and natural gas development, the entire relation between hydroelectric and steam power has changed. The conditions on large interconnected power systems, too, necessitate further analyses of steam and water power relations. It is evident, therefore, that a small efficiency increase in hydroelectric plants becomes of even greater importance now than it has been in the past and that further vigorous research work will doubtless show the way to these efficiency increases. Pumped storage, for which some new pump-turbines have been developed, may materially affect water and steam-power relations; frequency and load control systems, it is claimed, have improved plant efficiencies as much as 8 or 10 per cent; there have been many improvements in valves, piping and accessories, design of water passages and of water wheels themselves. If we can judge by the results of research during the past 10 yr. in reducing the cost of the kilowatt-hour from water power, the hydraulic engineer now has in this research a powerful weapon for reducing it still further during the next 10 yr.

It is to be expected that he will use it with the same alertness and effectiveness as manifested in the past.

Fifty-second Annual Meeting of the A. S. M. E.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, AT MEETING NOVEMBER 30 TO DECEMBER 4, GAVE SPECIAL ATTENTION TO HIGH-PRESSURE BOILERS, BOILER FEEDWATER STUDIES, PERFORMANCE OF MODERN STEAM GENERATING UNITS, FLUXING ASHES

THAT THE INTERESTS of the mechanical engineering profession are broadening is evident from the program which attracted two thousand engineers to register at the Fifty-second Annual Meeting of the American Society of Mechanical Engineers held in the Engineering Building in New York City, November 30 to December 4. One could not help being impressed with the diversity of the subjects which were given consideration. To the engineer, of course, the technical sessions seemed to make an especial appeal and at these

CONRAD N. LAUER WHO WAS INSTALLED PRESIDENT OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

55 papers were presented and discussed. The sessions were distributed among the following branches of the engineering field: machine shop and applied mechanics, materials handling, metal cutting, fluid meters, industrial power, casting and machine design, railways, lubrication, stabilization, fuels, hydraulics, textiles, engineering economics, steam tables, student branches conference, central station power, management research, steel mill bearings, aeronautics, boiler feedwater studies, oil and gas power, metal rolling and education and training.

In addition to the technical sessions, three lectures were on the program, all of which were well attended, and dealt with subjects of general interest to engineers. The Henry Robinson Towne lecture was delivered this year by W. B. Donham, of Harvard University, who took as his subject the temporary emergency and twenty-year planning. Miss Frances Perkins, industrial commissioner of the state of New York, addressed the meeting on the State Labor departments and professional engineers—coöperation essential to progress in accident prevention. The Robert Henry Thurston lecture was delivered by Edward L. Thorndike, of Columbia University, on Psychology and Engineering.

At the meeting known as President's Night, held Tuesday evening, Roy V. Wright, president of the Association, selected as his address The Engineer Militant. Other features of the program were the report of the Tellers of Election of officers for 1931 and '32, these of the Philadelphia Gas Works; Vice Presidents, R. M. officers being, President, Conrad N. Lauer, President Gates, New York; W. B. Gregory, New Orleans, La.; F. H. Dorner, Milwaukee, Wis., and C. M. Allen, Worcester, Mass. For managers, E. W. O'Brien, Atlanta, Ga.; H. R. Westcott, New Haven, Conn., and A. J. Dickey, San Francisco, Calif.

Another feature of the program was the conferring of Honorary Membership on Dr. Palmer C. Ricketts, President of the Rensselaer Polytechnic Institute, in recognition of his contributions to engineering education.

The A.S.M.E. Gold Medal was conferred upon Albert Kingsbury for his research and development work in the field of lubrication. The Melville Award went to Arthur E. Grunert for his paper on comparative performance of a pulverized coal-fired boiler using bin system and unit system of firing. The Junior Award was conferred upon M. K. Drewry for his paper on radiant superheater development. The Charles T. Main Award went to Robert Elmer Klise for his paper on interchangeability—its development and significance in industry. The Student Award went to Jules Podnossoff for his paper on pressure and energy distribution in multi-stage steam turbines operating under varying conditions.

At the Annual dinner to new members, which was held in the Hotel Astor, a feature of especial interest was the presentation of Honorary Membership to Dr. Calvin W. Rice, who has been secretary of the Society for the past 25 yr.

Industrial Power

THAT INDUSTRIAL power engineers are thinking in terms of high pressure and large capacity units is evident from the character of the three papers selected for presentation at this session of the meeting. The first dealt with a description of the Ford Motor Co.'s 1200-lb. steam plant installation and was presented by A. R. Smith of the General Electric Co. and H. B. Hanson of the Ford Motor Co.

This plant is interesting from the standpoint that it is an industrial power plant of 110,000 kw. capacity, using steam generated at 1200 lb. pressure. It serves the Ford plant at River Rouge and replaces and occupies no more space than equipment which had only one-eighth its capacity. The change has been made without interruption of service and with little or no exterior evidence of such a complete rehabilitation.

Major apparatus in the main steam power plant consisted of four boilers of 250 lb. steam pressure, 600 deg. F., 250,000 lb. capacity and four similar boilers

which had been rebuilt and modernized 2 yr. ago to have an evaporating capacity of 500,000 lb. each. The turbine equipment consisted of four 50,000-kw. units and two 12,500-kw. units. It was decided to increase the generating capacity by substituting larger units for the 12,500-kw. turbines and to reconstruct that half of the turbine room where these units were located to get the maximum turbine capacity possible consistent with high efficiency and proper operating conditions. The plan finally selected calls for two 110,000-kw. turbines in that space.

As now equipped, the capacity of the plant is one 110,000-kw. turbine, four 30,000-kw. turbines, two 30,000-kw. Detroit Edison tie-lines, totalling 290,000-kw. with provision for a second 110,000-kw. turbine. The electrical system which carries a potential of 13,800 v., is divided into four sections, each bus section being connected through current eliminating reactors to a common synchronizing bus. There will be connected to each section of bus, one half of the capacity of each 110,000-kw. turbine generator and one 30,000-kw. turbine, while the Edison tie-lines will be connected to the synchronizing bus.

Prevailing steam conditions were not conducive to high economies and inasmuch as four of the boilers were to be completely remodelled to increase their output, it seemed logical to resort to 1400 lb. steam pressure. This higher steam pressure, aside from its economic advantage, was of great importance because of the then limited supply of condensing water, or the possibility of reducing the size of the tunnel under consideration and since constructed. The possibility of ultimately providing extraction steam for general process work in the factory was another consideration for using a higher steam pressure.

W. A. Shoudy brought out in the discussion of this paper the fact that this is the largest industrial power plant in the world. Other points of interest to him were the equal distribution of capacities in high and low pressure turbines. He questioned if the type of turbine is the one desired for an industrial plant and thought that accessibility had been sacrificed for floor space saving. Large units of this type, he thought, are not of general interest in industrial power.

Investigation of High-Pressure Boiler Characteristics

Characteristics of a High-Pressure Series Steam Generator was the title of a paper presented by Dean A. A. Potter, H. L. Solberg and G. A. Hawkins, all of Purdue University. To determine the characteristics presented in the paper, experiments were carried out on a steam generator consisting of two parallel circuits of seamless-steel tubing supplied with feedwater at one end and delivering steam from the other end at any desired pressure up to 3500 lb. per sq. in. and at a maximum temperature of 830 deg. F. The changes which take place in the circuit were measured by means of thermo couples and manifold pressure connections.

The unit was controlled automatically by a system which uses the thyratron vacuum tube circuit. A set of charts was presented showing the operation of automatic control on a swinging load. The tests reported in the paper indicated the effect of varying the steaming capacity at constant pressure and temperature, changing the pressure at constant capacity and temperature and increasing the steam temperature at constant capacity and two different pressures. The temperature and the pressure changes through the water and steam circuit were shown graphically. Data were also presented on the heat transfer rate through the furnace wall tube.

Results up to date indicate that this steam generator will operate successfully at any pressure between 1500 and 3500 lb. per sq. in. and at a maximum temperature which is limited by the materials used. Automatic control held the steam pressure and temperature nearly constant through the range of operation.

Series Type Boilers for High Pressure

In another paper presented at this same meeting, H. J. Kerr, of the Babcock & Wilcox Co., described the development of series type boilers from the early stages which resulted in the Calumet steaming economizer type now in extensive use to the once-through series boiler. This paper described the operation of the latter units from 1500 to 5000 lb. per sq. in. and presented test data. The limiting factors of this type of unit, such as equalization of flow, control with variable capacity and operation, were discussed. Heat transfer data on high-pressure superheated steam were also presented.

The author stated that it was not his purpose to propose the immediate adoption of 2500 lb. pressure for power generation. The facts, however, appear to be that 2500 lb. steam pressure makes possible higher efficiency. The amount of this increased efficiency which will be available will depend upon the cost of obtaining it, and the type of unit described may make it possible under certain conditions to proceed further in this direction than with standard constructions. One can hardly operate the type of unit which he described without developing a definite conviction that 3000 lb. steam pressure with a unit of this type represents little complication as compared with the ordinary 600-lb. to 1500-lb. units so common at the present time. Again, the information developed gives data that can be used for the proper design of units of this type and which prior to the making of these tests were not available.

In discussion of these papers, George Orrok brought to mind the fact that Jacob Perkins designed and built his high-pressure series boiler in 1828 and only the lack of suitable instruments for measurements prevented him from proving to the world the great step he had made in the steam generation problem. It seems that at last the latest steps are being made to investigate the problem of evaporation in a tube, the theoretical knowledge of which has lagged many years behind the study of other lines of development. So little is known about the resistance of steam water mixtures in tubes that the working out of this material is highly desirable.

When employing higher steam pressures, higher steam temperatures can be used effectively, according to the statement made by Karl A. Mayr of the Siemens-Schuckertwerke. If one would use a steam temperature of 1000 deg. F. in connection with a steam pressure of only 300 or 400 lb. per sq. in., superheated steam would be blown into the condenser and part of the valuable superheat could not be converted into power by any means but would be carried away by the condenser cooling water.

If the temperature of 1000 deg. F. is maintained in connection with 1000 lb. per sq. in. steam pressure, a

highly efficient cycle is obtained. With higher steam pressures, more turbine bleeding and feedwater heating stages can be employed. Valuable heat can be transmitted to the boiler feedwater instead of carrying it to waste in the condenser cooling water.

It was the thought of I. E. Moultrop of the Edison Electric Illuminating Co. of Boston, that the cost of the higher pressure boiler has doubtless deterred many engineers from adopting it. The once-through series boiler promises to bring about a great reduction in boiler costs. To make the drumless series boiler commercial, it will be necessary to find means of absolutely insuring continuity of the feed. The quality of water is also an important item.

Operation of Benson boilers, according to M. Artsay, seems to indicate that troubles due to scale deposits are reduced to a great extent if the vapor phase is eliminated, on the other hand, operation of high fluid velocity coil boilers also indicates reduction of scale deposition.

As a contribution to this discussion, D. Robert Yarnall, presented a description of the new high-pressure testing plant which has recently been built by the Yarnall-Waring Co. and described in the Dec. 1 issue of Power Plant Engineering.

Fluxing of Ashes

ONLY ONE session of the meeting was devoted to the subject of fuels and this was taken up entirely by the presentation and discussion of a paper entitled Fluxing of Ashes and Slags as Related to the Slagging Type Furnace. The paper was presented by P. Nicholls and W. T. Reid, both of the U. S. Bureau of Mines. This paper was prepared as a report for the special research committee on the removal of ash as molten slag from powdered coal furnaces. The primary object of the investigation was to obtain data on the flowing of coal ash slag to enable users of slagging type boilers to increase the fluidity of the deposited ash should it not be possible to tap at available furnace temperatures.

Studies were made using a platinum-wound furnace supplemented by a gas furnace with a 32-in. by 28-in. hearth. A standard of fluidity desirable for easy tapping was established and the results were expressed as the temperature necessary to produce this fluidity, designated the flow temperature. Values of flow temperatures in terms of chemical composition of the ash or ash plus flux were determined for a range of ashes found in American coals and for additions of the following fluxes: iron ore, limestone, dolomite, fluorspar, salt cake, steel slags and some less important minerals.

It was deduced that limestone or dolomite would be the most economical material to use for slagging-type boilers as now built, and from a diagram which was presented the quantity of flux can be computed. The investigation was carried beyond present requirements for slagging type boilers and to flow temperatures below 2400 deg. F. A complete diagram was given for coal ash-lime-iron showing the flow temperatures plotted against composition.

The discussion brought out the fact that conditions of operation have much to do with the difficulty encountered with slag tapping furnaces. J. P. Mailler, stated that he had experienced difficulty getting the slag out at times, due to the fact that the load on the boiler was low and the furnace temperature below the freezing point of the slag. This could be overcome only by carrying a heavier load which was not always easy to arrange.

On the other hand, M. K. Irwin, who operates a base load plant, experienced no difficulty with slag type furnaces as his boilers are operated at high load factor. The principal advantage he sees in this type of furnace is that cheaper coals may be used.

Central Station Practice

THAT THE performance of a centrifugal fan may be influenced considerably by the direction and velocity of approach of the air to the inlet is well known by engineers and it was to present experimental results of tests to ascertain the effect of inlet boxes on the performance of induced draft fans that Lionel S. Marks of Harvard University and E. A. Winzenburger of the Waltham Watch Co. presented their paper entitled Influence of Inlet Boxes on the Performance of Induced Draft Fans. The tests showed the magnitude of the changes in performance that can be expected and emphasized the need for testing fans with their inlet boxes attached. The conclusion drawn from the tests was that it is not sufficient for the fan user to know the characteristics of a selected fan with free inlet but he also should know the characteristics when the inlet box is attached.

This paper was presented as preliminary work on a subject which will be extended in the future.

PERFORMANCE OF LARGE BOILERS

C. F. Hirschfeld and G. U. Moran, both of the Detroit Edison Co., presented the second report on the performance of steam generating units which was in reality a progress and preliminary paper from which the authors did not wish definite conclusions to be drawn. The paper was based on data collected upon the operation of 244 large steam boilers over a period of 3 yr. The previous paper on this subject was presented at the 1929 Annual Meeting of the A.S.M.E. and covered only one year's records but it was thought advisable to continue for at least 2 yr. in order to obtain more conclusive results.

The primary object was to study boiler outages with special attention given to causes, frequency and duration, and the effect of such factors as severity of use, design, fuels and methods of firing on boiler reliabilities. The paper presented at this time gives only a general summary of the data and a short discussion of the results. But it is proposed to follow this by more complete analysis of individual records in the near future.

Feedwater Studies

AS A RESULT of investigations carried out at the University of Illinois by Frederick G. Straub, he prepared a paper entitled Solubility of Calcium Salts in Boiler Waters. The object of the investigation was to determine the behavior of various chemicals found in boiler waters at elevated temperature. This included a study of the solubility of various compounds under conditions simulating those found in high-pressure boilers. The study involved the determination of the solubility of more insoluble compounds such as calcium carbonate and calcium sulphate separately and combined, as well as in the presence of the more soluble salts such as sodium carbonate, sodium sulphate and sodium hydroxide. The results obtained should aid materially in determining the proper water treatment for high pressure boiler operation.

As a result of his experiments, the author concluded that the solubility of calcium carbonate decreases with increase in temperature; the solubility of calcium carbonate in the presence of sodium carbonate or hydrate is practically zero at the temperatures studied; the solubility of calcium sulphate is not directly proportional to the sulphate in solution; calcium sulphate as a solid phase cannot exist in equilibrium with solutions containing sodium carbonate, even at pressures up to 1500 lb.; the old calculated ratios of CO_2/SO_4 to prevent calcium sulphate formation as a solid phase are extremely high.

Foaming and priming of boiler water was discussed by C. W. Foulk of the Ohio State University in an extremely interesting paper which was accompanied by moving pictures showing the action of foaming water in a specially constructed glass boiler. New information about the behavior of suspended solids and of dissolved salts was brought out and a helpful theory of foam formation was advanced. It would be inferred, however, from recent works that too broad generalizations in regard to foaming and proming of boiler water should not be made, because in some cases the design of the boiler profoundly affects the behavior of the water.

In a discussion of this paper, J. A. Holmes of the National Aluminate Co. stated that he had constructed a boiler of one gallon capacity capable of withstanding 1000 lb. pressure and equipped with sight glasses at the surface to observe boiling characteristics. This boiler has been forced to evaporate up to 500 per cent of its nominal rating. Only natural waters have been experimented with and he has found the theories advanced by the author helpful in explaining some of the phenomena observed. He stated that in operating the boiler at pressures below 450 lb. the steam in the boiler was clear whereas the water was dark. But as the pressure was increased the water become clear at 600 lb. pressure and the steam was dark, which he thought was explained by some of the theories that Mr. Foulk advanced.

A. R. Mumford of the New York Steam Corporation stated that in their endeavor to reduce foaming they had found three methods, an application of one of which would usually result in satisfactory operation. These methods were to reduce the water level in the boiler, reduce the rate of steaming, or reduce the concentration of hydroxyl ion.

Oil and Gas Power Session

ALL THE papers presented at the session on oil and gas power had to do with marine Diesel practice except that relating the progress in the field. In this paper which was presented by L. R. Ford, it was stated that a feature of power plant practice that was receiving attention is the possibility of using oil engines in conjunction with steam engines to balance steam and power output. An outstanding example of this sort of application is to be found in the plant of R. H. Macy & Co., New York City.

Further progress has been made toward the determination of the costs of power in stationary Diesel plants as a result of the sub-committee work on oil engine power costs. What will be when completed the largest Diesel power plant in existence is projected by the city of Vernon, Cal., which will include five M.A.N. type two cycle double acting engines of 7000 b.hp. which are now under construction by Hooven-Owens-Rentschler.

News Notes

PLIBRICO JOINTLESS FIREBRICK Co., Chicago, Ill., announces appointment of the Brakel Engineering Co., 1006 Washington Ave., Houston, Texas, as its distributor in Southern Texas and appointment of F. F. Kimball, care of H. H. Smith Storage Co., 1015 Mulberry St., Kansas City, Mo., as its distributor in the Kansas City territory.

GALION, OHIO, plans boiler room additions to its municipal light and power plant, estimated cost $175,000. Hadlow, Hughes, Hick & Conrad, Inc., 850 Euclid Ave., Cleveland, Ohio, is engineer.

DONALD FRASER, director and former vice president of Chain Belt Co., Milwaukee, Wis., died on Nov. 20, at the age of 78. Mr. Fraser, formerly engaged in the pattern-making business in Minneapolis and Milwaukee, came to the Chain Belt Co. in 1895. He subsequently became vice-president and works manager, retired in 1917, and was made a director of the company. He was also a director of the Sivyer Steel Casting Co. and the Federal Malleable Co., both of Milwaukee.

WELLMAN ENGINEERING Co. of Cleveland, Ohio, announces that it has acquired by purchase the clam shell bucket and heavy-duty trailer business of the G. H. Williams Co. of Erie, Pa., including good-will, drawings, patterns, inventions, patents, and that the engineering, manufacture and sale of these products will be immediately transferred to the Wellman Engineering Co. plant in Cleveland. W. C. Swalley, secretary and general manager; A. J. Lichtinger, assistant manager; C. F. Weiblen, sales manager; and P. T. Robin, chief engineer of the G. H. Williams Co. will be associated with The Wellman Engineering Co. at Cleveland in the manufacture and sale of this equipment. These two lines will continue to be marketed under their trade names.

PAUL S. CLAPP resigned Dec. 3, as managing director of the National Electric Light Association to accept election as vice-president of the Columbia Gas and Electric Corp. Mr. Clapp became managing director of the N.E.L.A. on October 15, 1926, succeeding M. H. Aylesworth. Prior to his connection with the National Electric Light Association, Mr. Clapp was special assistant to the Secretary of Commerce. He was born in Iowa and graduated from Iowa State College at Ames as an electrical engineer. He served as captain in the United States Army Signal Corps. From December, 1918, to February, 1919, he was associated with the Peace Commission in Paris as a member of the committee for the determination of damage in allied countries. Subsequently he established and supervised the telephone and telegraph service between the various capitals of Europe, by which the relief work was administered. His home is in New York City.

AJAX FLEXIBLE COUPLING Co., Westfield, New York, recently received an order for over 800 flexible couplings, all to be used on the conveyor drives to be installed in the new Chicago Post Office. Couplings with interchangeable identical flanges, using rubber bushings, graphited bronze bearings, alloy steel drive studs and designed to require no lubrication will be furnished.

FARNSWORTH Co. announces that it has moved to Watertown, N. Y., and that The Bagley and Sewall Co. will manufacture all its equipment in the future.

NORTHERN EQUIPMENT Co., Erie, Pa., announces the appointment of Irving M. Day, 306 Chandler Building, Washington, D. C., as representative for its equipment; also G. L. Simonds, Winter Haven, Fla., as representative in the State of Florida.

ANNOUNCEMENT is made that Hall Laboratories, Inc., Hagan Corp. and The Swann Corp. have formed a new company known as the Buromin Co. with headquarters at 309 Bowman Bldg., Pittsburgh, Pa. Their purpose in forming this new company, it is stated, is to make available to small plants the Hall system of boiler water conditioning. The Buromin Co. has secured from Hall Laboratories, Inc., the rights to practice in the small plants of this country the patented Hall method of boiler water conditioning. The company has retained Hall Laboratories as its consultants, in order to have its advice on any unusual problem. The company has secured from Hagan Corp. the right to sell Hagan Phosphate as Buromin, and it has reached an agreement with the Swann Corp. for the manufacture of Hagan Phosphate in liquid form.

OFFICERS elected for 1932 by the Exhibitors Committee, Industrial and Power Shows, Inc., are as follows: President, C. F. Radley, Oakite Products, Inc., New York; vice-president, Victor Wichum, C. J. Tagliabue Mfg. Co., Boston; secretary, G. S. Carrick, American Arch Co., New York; treasurer, J. P. Ferguson, Reading Steel Casting Co., Bridgeport. Other directors are: L. W. Shugg, General Electric Co., Schenectady; H. S. Wheller, L. J. Wing Mfg. Corp., New York; S. G. Bradford, Edge Moor Iron Co., Edge Moor, Del.; F. C. Eibel, Worthing-

ton Pump and Mfg. Co., Harrison, N. J.; R. H. Bacon, Fairbanks, Morse & Co., Inc., Chicago; W. W. Bertram, Morse Chain Co., New York; L. F. Gordon, Southern Power Journal, Atlanta; E. J. Billings, Babcock & Wilcox Co., New York.

MATERIALS HANDLING INSTITUTE was formed at Cleveland, Ohio, on Dec. 8 at a meeting of over 70 manufacturers of equipment to promote better understanding of the methods of materials handling and coöperation between various groups. Officers elected were: F. E. Moore, president; J. B. Webb, vice president; H. W. Standert, treasurer; J. A. Cronin, secretary; also a board of governors representing eleven divisions of equipment with power to add to their number and appoint committees.

F. A. MERRICK, President of the Westinghouse Electric and Manufacturing Company made the following announcement:

"Westinghouse Electric and Mfg. Co. and the Westinghouse Electric International Co. announce that they have concluded with Eroole Marelli & Co. in Milan, Italy, a leading Italian Electric Manufacturing concern, an agreement for an exchange of patents and experience. The Westinghouse companies do not participate financially nor take any part in the management of the Italian company."

H. H. LAMENT, vice-president of Sharples Specialty Co., announces the appointment of Carl J. Lamb as New York district manager. Mr. Lamb, a former naval officer has previously been in engineering with E. I. DuPont de Nemours Co., Sinclair Consolidated Oil Co. and Westinghouse Electric & Mfg. Company.

Catalog Notes

CURTIS ENGINEERING SPECIALTIES, including pressure regulators, traps, strainers, temperature regulators, water regulators, damper regulators, pump and engine regulators, valves and a wide variety of steam specialties are described and illustrated in detail in a new 92-page bulletin, No. 61, just published by Julian d'Este Co., 6 Spice St., Boston, Mass.

ARMSTRONG TRAP MAGAZINE, issued by Armstrong Machine Works, Three Rivers, Mich., has in the December number some interesting facts on trap action, storage of hot water and operation of unit heaters.

FOR HANDLING heads higher than practicable for a single stage centrifugal pump, a two-stage pump having single suction impellers placed back to back, that is, with the suction openings facing towards the ends of the shaft, is described in catalog B-3, issued by the De Laval Steam Turbine Co., Trenton, N. J. The new pump is hydraulically balanced, has but two pairs of wearing rings and, because of the reduced leakage, limited surface in contact with moving water and relatively high speed and high head per stage, the efficiency is relatively high.

MOTOR GENERATORS, reasons for their uses, construction of Elliott motor-generators, together with discussion of type, sizes, operation and applications are given in a new letter-size, well illustrated bulletin No. 0-1 just published by Elliott Co., Jeannette, Pa. Copies of the bulletin can be obtained from Elliott Co.'s district offices or from the electric power division at Ridgway, Pa.

RADIAFIN TUBES for heaters and coolers and heating and cooling units that can be made of them are fully described and illustrated in bulletin No. 11-S recently issued by Schutte & Koerting Co., Philadelphia, Pa.

WESTON ILLUMINOMETER for measuring directly in foot-candles the intensity of illumination at any point is illustrated and described in a circular issued by the Weston Electrical Instrument Corp., Newark, N. J.

STONE STOKER DRIVE, with worm gear for any speed reduction from 5 to 1 up to 100 to 1 so that motor, turbine or engine drive may be used or even a dual alternative drive, is described in a folder issued by the Johnston & Jennings Co., Cleveland, Ohio.

Acknowledgment

THOSE WHO have done most towards the development of power plant equipment are the manufacturers who have led in producing equipment incorporating the latest scientific ideas. To these the editors of Power Plant Engineering appealed for information in the preparation of this issue and we take this opportunity to acknowledge our appreciation of assistance received from the following manufacturing concerns:

The Air Preheater Corp., New York, N. Y.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
American Engineering Co., Philadelphia, Pa.
American Pulverizer Co., St. Louis, Mo.
Amthor Testing Instrument Co., Inc., Brooklyn, N. Y.
Atlas Valve Co., Newark, N. J.
Babcock & Wilcox Boiler Co., New York, N. Y.
Bailey Meter Co., Cleveland, Ohio.
Boiler Engineering Co., Newark, N. J.
Borden Co., Warren, Ohio.
Brady Conveyors Corp., Chicago, Ill.
C. F. Braun Co., Alhambra, Calif.
Buffalo Meter Co., Buffalo, N. Y.
Bundy Steam Trap Co., Nashua, N. H.
Burt Mfg. Co., Akron, Ohio
Climax Engineering Co., Chicago, Ill.
Clipper Belt Lacer Co., Grand Rapids, Mich.
Cochrane Corp., Philadelphia, Pa.
Cokal Stoker Corp., Chicago, Ill.
Combustion Engineering Corp., New York, N. Y.
Connery & Co., Inc., Philadelphia, Pa.
Dampney Co. of America, Boston, Mass.
DeLaval Separator Co., New York, N. Y.
DeLaval Steam Turbine Co., Trenton, N. J.
Detroit Stoker Co., Detroit, Mich.
Julian d'Este Co., Charlestown, Mass.
Diamond Power Specialty Corp., Detroit, Mich.
Dust Recovering & Conveying Co., Cleveland, Ohio.
Edge Moor Iron Co., Edge Moor, Del.
Electric Controller & Mfg. Co., Cleveland, Ohio.
Electric Machinery Mfg. Co., Minneapolis, Minn.
Elgin Softener Co., Elgin, Ill.
Elliott Co., Jeannette, Pa.
The Engineer Co., New York, N. Y.
Erie City Iron Works, Erie, Pa.
Foote Bros. Gear & Machine Co., Chicago, Ill.
Foster Wheeler Corp., New York, N. Y.
Fuller Lehigh Co., New York, N. Y.
Gardner Denver Co., Quincy, Ill.
General Insulating & Mfg. Co., Alexandria, Ind.
Green Fuel Economizer Co., Beacon, N. Y.
Homestead Valve Mfg. Co., Coraopolis, Pa.
The Iron Fireman Mfg. Co., Portland, Oregon.
Johnston & Jennings Co., Cleveland, Ohio
Kaye & MacDonald, Inc., West Orange, N. J.
Kennedy Van Saun Mfg. & Engrg. Corp.
The King-Seeley Corp., Ann Arbor, Mich.
Leavitt Machine Co., Orange, Mass.
Jas. Leffel & Co., Springfield, Ohio
The Linde Air Products Co., New York, N. Y.
Link-Belt Co., Chicago, Ill.
Ludlow Valve Co., Troy, N. Y.
The Marley Co., Kansas City, Mo.
Maxim Silencer Co., Hartford, Conn.
Merco Nordstrom Valve Co., San Francisco, Calif.
Mercon Regulator Co., Chicago, Ill.
Moore Steam Turbine Corp., Wellsville, N. Y.
Moto Meter Gauge & Equip. Co., Toledo, Ohio
Murray Iron Works Co., Burlington, Iowa
National Aluminate Corp., Chicago, Ill.
Nordberg Mfg. Co., Milwaukee, Wis.
The Northern Blower Co., Cleveland, Ohio
Northern Equipment Co., Erie, Pa.
Pennsylvania Pump & Compressor Co., Easton, Pa.
Pickering Governor Co., Portland, Conn.
Wm. S. Pierce Co., Buffalo, N. Y.
Rains Metallic Packing Co., Spokane, Wash.
Reliance Gauge Column Co., Cleveland, Ohio
Ric-Wil Co., Cleveland, Ohio
Riley Stoker Co., Worcester, Mass.
Ruggles-Klingemann Mfg. Co., Salem, Mass.
Sarco Co., New York, N. Y.
Schubert-Christy Corp., Afton, St. Louis Co., Mo.
Schutte-Koerting Co., Philadelphia, Pa.
Skinner Engine Co., Erie, Pa.
Spraco, Inc., Summerville, Mass.
Steam & Combustion Co., Chicago, Ill.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Strong-Carlisle & Hammond Co., Cleveland, Ohio
Strong-Scott Mfg. Co., Minneapolis, Minn.
Superior Gas Engine Co., Springfield, Ohio
Toledo Pipe Threading Machine Co., Toledo, Ohio
Tube Turns, Inc., Louisville, Ky.
Union Carbide & Carbon Corp., New York, N. Y.
Union Iron Works, Erie, Pa.
United Air Cleaner Co., Chicago, Ill.
U. S. L. Battery Corp., Niagara Falls, N. Y.
Viking Pump Co., Cedar Falls, Iowa
Henry Vogt Machine Co., Louisville, Ky.
The E. H. Wachs Co., Chicago, Ill.
Walworth Co., Boston, Mass.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Worthington Pump & Machinery Corp., Harrison, N. Y.
Yarnall-Waring Co., Philadelphia, Pa.